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Sheep Research Program

Progress Report No. 4

Roman L. Hruska U.S. Meat Animal Research Center
in Cooperation With
University of Nebraska, Agricultural Research Division,
The Institute of Agriculture and Natural Resources

CONTENTS

ROMAN L. HRUSKA
U.S. MEAT ANIMAL RESEARCH CENTER[1]

1. Overview of Center: The U.S. Meat Animal Research Center (MARC) is part of the U.S. Department of Agriculture's Agricultural Research Service. MARC was authorized by Congress on June 16, 1964, thereby creating a single facility that provides an unusual opportunity for making major contributions to the solution of problems facing the U.S. livestock industry. Development of the 35,000-acre facility started in the spring of 1966. The office-laboratory buildings provide a physical plant for about 80 scientists and about 200 support personnel. In addition, the University of Nebraska's Great Plains Veterinary Educational Center (GPVEC) provides a facility for four university faculty members, support personnel, and pre- and post-DVM students.

Approximately 50 percent of the research program is devoted to beef cattle, 30 percent to swine, and 20 percent to sheep. Current research program objectives require breeding age female populations of approximately 7,250 cattle (20 breeds), 4,250 sheep (10 breeds), and 600 crossbred swine litters to carry out the various experiments. Additional swine facilities constructed in 1991-1992 will provide space for over 700 litters per year.

The research program at the Center is organized on a multidisciplinary basis and is directed toward solving problems for the U.S. livestock industries. The seven research units are Genetics and Breeding, Nutrition, Reproduction, Meats, Animal Health Systems, Biological Engineering, and Production Systems. The research program complements research conducted elsewhere by the U.S. Department of Agriculture and is cooperative with the University of Nebraska Institute of Agriculture and Natural Resources and other land grant university agricultural experiment stations throughout the country.

On October 10, 1978, the President signed into law a bill renaming the U.S. Meat Animal Research Center the Roman L. Hruska U.S. Meat Animal Research Center. The purpose of the bill was to honor former Nebraska Senator Roman L. Hruska for ''his efforts in the establishment of a centralized facility for the research, development, and study of meat animal production in the United States.''

2. Overview of Sheep Research Program: MARC's sheep research program places the highest priority on developing technology capable of having an immediate and long-term impact on the sheep industry. The program includes research and development of technology that can be practically implemented by small farmers and commercial producers alike.

Currently, we have 60 research scientist and research associate positions at MARC. There are 30 research projects in beef cattle, sheep, and swine.

This report represents a cross section of our sheep research program at the present time. Since some of the projects from which results are reported are still in progress, the preliminary nature of some of the results must be recognized. However, it is our opinion that information useful to the industry should be provided at the earliest possible time. Progress reports of this nature will be released periodically to make current results available to the sheep industry.

3. Appreciation: I want to express my appreciation to the scientists for their contributions and to Sue Karges, Public Affairs Specialist, for organizing and editing this report.

D.B. Laster, Center Director
Roman L. Hruska
U.S. Meat Animal Research Center

Sheep Facilities and Flock Management at MARC

Mike H. Wallace and Gary S. Ross[1]

Facilities, breeds and staffing

The sheep research program at MARC utilizes 1,500 acres of pasture consisting of 160 acres of irrigated brome, 480 acres of warm season perennial, and 860 acres of dryland brome. About 4,300 head of ewes are maintained on various levels and types of management to fit research requirements. About 450 purebred and crossbred stud rams are maintained, utilized, and studied, and over 6,000 head of lambs are produced, fed, and studied yearly.

Twenty-four buildings specifically designed for sheep handling efficiency, comfort, and welfare are utilized. The needs of the sheep, lambs, and most research projects are met by a staff of 12 permanent and 4 temporary employees through the year. A description of the facilities, breed types, and staffing follows.

Two buildings are 900-head drylot wintering and lamb feedlot facilities used in conjunction with a 900-ewe raised slotted floor lambing facility, and a 1,000-head raised slotted floor feedlot. These facilities provide the needs for 650 Northwest whiteface ewes, 500 head of ½ Columbia, ¼ Suffolk, ¼ Hampshire (S-III) ewes, 500 head of Booroola Merino-Finnsheep comparison ewes and 600 head of half-Finnsheep crossbred ewes. Lambings are scheduled for January, March, and May-June.

There are three 380- to 420-ewe drylot lambing and feedlot facilities. They provide the needs of 700 head of purebred Dorset, purebred Finnsheep, purebred Romanov, and homozygous Booroola Merino ewes, and 460 mostly half-Finnsheep and other crossbred ewes. Lambing is scheduled for February, April, and May-June.

Two polesheds are 500 head ewe drylot lambing and feedlot facilities. Shepherds care for 500 head of S-III ewes and 500 head of purebred Texels and Suffolks. Lambing is scheduled for February and March-April.

A quarter-section pasture includes 8 structures for ram housing and/or photoperiod control with enclosed sorting and handling facilities. There are 450 purebred and crossbred stud rams.

The main building has a shop area, 250-head artificial rearing room, automated feed-monitoring devices for about 120 head, and an office area.

There is a building housing the main shearing area, covered sorting and load-out facilities, and sheep sale area. A 25-acre pasture includes 5 structures for management of sheep requiring biological isolation.

Needs of experiments requiring very intensive observations under highly controlled environments for sheep and other species, including laboratory animals, are provided.

Flock management

Eleven thousand sheep and lambs at MARC may be on as many as 20 experiments at any one time. MARC has approximately 4,300 ewes lambing in facilities varying from slotted floor confinement to conventional drylot sheds. Although experimental protocol and facility type dictate variations in management, some standardized procedures are practiced.

Four to six weeks before lambing, ewes are sheared, drenched with Levamisol-HCl, vaccinated with eight-way Clostridial Bacterin/toxoid, treated for external parasites with

Ectrin pour-on, and given an injection of vitamins A, D, and E. At this time, ewes are switched from the maintenance ration to the late gestation ration (Table 1).

Table 1—Breeding sheep rations[a]

Maintenance Ration —	
42.0% dry matter	97.0 % corn silage
10.0% crude protein	0.7 % mineral supplement[b]
70.0% TDN	2.3 % soybean meal
Late Gestation Ration —	
51.0% dry matter	78.0 % corn silage
13.1% crude protein	0.75% mineral supplement[b]
70.0% TDN	4.25% soybean meal
	7.0 % corn
	10.70% chopped alfalfa hay
Lactation Ration —	
52.0% dry matter	76.0 % corn silage
16.1% crude protein	0.80% mineral supplement[b]
71.0% TDN	8.80% soybean meal
	4.4 % corn
	10.00% chopped alfalfa hay
Pasture Mineral Supplement —	
	65.0% trace mineralized salt
	16.0% steamed bone meal
	16.0% limestone
	3.0% mineral oil

[a]Due to round of numbers, final ration totals may not equal 100%.
[b]Mineral supplement consists of 22% limestone, 32% trace mineralized salt, 32% steamed bone meal, 6% soybean meal, 636 gm/T monensin, 5% sodium sulfate, and 1930 gm/T antibiotic.

When the first lamb in a flock is born, all ewes are switched to a lactation ration (Table 1) with a higher protein density. At parturition, lamb navels are bathed in a 7% tincture of iodine solution. A ewe and her lambs are individually penned, or "jugged", and her udder is checked for milk supply and function. Ewes and lambs remain jugged for 1 to 2 days and are observed for nutritional status of the lambs. Lambs not receiving adequate milk are fed 2 to 4 oz of bovine colostrum via stomach tube as needed.

When a ewe can't raise an entire litter, excess lambs are removed for artificial rearing or are crossfostered onto another ewe shortly after tagging (1 to 2 days of age). Tagging involves weighing and eartagging lambs and paint-branding lambs and ewes. Ewes and lambs are paint-branded with consecutive numbers starting with the first ewe lambing in a flock. Crossfostering is accomplished by use of the English fostering crate and/or "slime" method.

Lambs to be artificially reared are placed in the nursery facility at 1 to 2 days of age. The 900 lambs entered yearly in the nursery are given 2 to 4 oz of bovine colostrum and trained to the use of nipples. Lambs are self-fed on a commercially prepared ewe milk replacer until weaning at about 4 weeks of age. Lambs are tail docked, vaccinated for contagious ecthyma (sore mouth), and vaccinated with types C and D Enterotoxemia antitoxin at 3 to 7 days of age. After weaning, lambs begin an adaptation to the less controlled environment to be encountered when they return to their flock.

At about 2 days post-partum, ewe-lamb(s) pairs are

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[1]Wallace is sheep operations manager; and Ross is herd health veterinarian.

moved to a mixing pen with 5 to 15 other pairs of about the same age. They remain in this group and are closely observed for signs of mis-mothering and health problems until docking with emasculators at about 7 days of age. Two to three days after docking, ewes and lambs in mixing pens are moved to rearing pens containing 30 to 70 pairs. Pairs will remain in their rearing pens until weaning at 49 to 60 days of age. All lambs are given free access to creep feed while in the rearing pens.

Weaning procedures vary considerably by flock and type of rearing facility. In general, the ewe ration is changed to maintenance levels a few days pre-weaning and ewes are not fed on weaning day. Ewes and lambs are separated. Lambs are weighed; given an injection of vitamin A, D, and E; vaccinated with eight-way Clostridial Bacterin/toxoid, sorted by sex; and placed back in rearing pens. Ewes are drenched with fenbendazole and individuals are culled. Ewes are culled for: 1) mastitis or any udder dysfunction; 2) vaginal or uterine prolapse; 3) severe emaciation; 4) severe over- or underbite; 5) broken mouth; 6) chronic respiratory problem; 7) rupture; 8) failure to lamb or rear a lamb in two consecutive lambing seasons; and 9) failure to keep up with the flock movement during a normal drive. These ewes are sold as slaughter culls. The sound, "keeper", ewes are placed on pasture.

After a 2-week post-weaning adjustment period, lambs may be moved to, or put on, various research studies. Lambs are routinely self-fed ground-mixed complete rations (Table 2).

During the summer, or between weaning and breeding, all ewes are drenched with Levamisol-HCl, and their feet are trimmed and bathed for 1 hour in a zinc sulfate-soap solution.

Ewe lambs designated to be saved for replacement stock are sheared; drenched with Levamisol-HCl; vaccinated for Hairy Shaker Syndrome (BVD), Enzootic Abortion (EAE), and vibrio; and moved to pasture at 5 to 6 months of age and fed limited quantities of concentrates. All replacement ewe lambs are bred at 7 months of age to lamb at 12 mo. All ewes are drenched with oxfendazole and vaccinated for vibrio and enzootic abortion and vaccinated with a killed BVD vaccine prior to the 35-day breeding periods. Most matings are done on a single-sire basis to maintain sire identity.

MARC's 450 breeding rams are sheared during late May, drenched with Levamisol-HCl during December and July, and fenbendazole in September. In March, rams are drenched with oxfendazole and vaccinated with eight-way Clostridial Bacterin/toxiod, and BVD. Testicles are palpated for abnormalities at times of drenching. Feet are trimmed and bathed twice yearly, Rams which have abnormalities of feet/legs, mouth structure, testicles, or repeatedly fail to have viable semen tests are sold as slaughter culls.

MARC's sheep research program places the highest priority on the development of intensive and semi-intensive sheep production system technology capable of having an immediate impact on the sheep industry. However, it is the duty and responsibility of the shepherds to ensure that the animals are available and healthy for research projects. Only through disciplined preventive programs such as the one outlined here may MARC's ultimate objective be reached: to help the industry produce red meat and wool more efficiently.

Table 2—Self-fed lamb rations

Lamb Creep, Ground-mixed (Lambs up to 60 lb) —
| 17.5% crude protein | 20% Alfalfa |
| 80.5% TDN | 80% Concentrate[a] |

Lamb Ration, Ground-mixed (Lambs 60-80 lb) —
| 14.5% crude protein | 20% Alfalfa |
| 81.6% TDN | 80% Concentrate[a] |

Lamb Finishing Ration, Ground-mixed (80 lb to slaughter) —
| 11.8% crude protein | 20% Alfalfa |
| 82.5% TDN | 80% Concentrate[a] |

Lamb Grower, Pelleted (Replacement breeding stock 80 lb to first breeding) —
| 14.4% crude protein | 50% Alfalfa |
| 67.4% TDN | 50% Concentrate[a] |

Dry Nursery Ration, Ground-mixed (2 days to 28 days for artificially reared lambs) —
24.8% crude protein	10.0% Alfalfa
85.4% TDN	56.8% Concentrate[a]
	15.0% Dextrose
	5.0% Corn Oil
	5.0% Whey
	0.2% Choline Chloride
	8.0% Oats

[a]Concentrate portion includes corn and soybean meal in proportions to meet protein and energy requirements. The following is also included as a portion of the total ration: 1.0% limestone. 0.5% trace mineralized salt. 0.5% steamed bone meal. 0.5% ammonium chloride, plus vitamins A, D, and E. 22 gm/T monensin. and 50 gram/T antibiotic

The Effect of Animal Age on Muscle Enzyme Activity and Their Relationship With Growth

Georgianna Whipple and Mohammad Koohmaraie[1]

Introduction

For most livestock production systems, the sale of meat animals for slaughter serves as a major source of income. Therefore, it is important to be able to understand the biological mechanisms involved in animal growth with emphasis on production of lean meat. Much work has been done at MARC in the area of muscle proteases (enzymes) and how they are involved in protein degradation whether it be in the live animal or after slaughter.

One of these protease systems is called u- and m-calpain, which requires calcium to be active. Both of these calcium dependent proteases are capable of breaking down certain muscle proteins. The pH or alkalinity for the optimum activity of these proteases is 7.5 which is close to the pH or alkalinity found in living animals. For these reasons, these proteases are believed to be involved in protein turnover relating to muscle growth. A protein that works as an inhibitor, calpastatin, which is capable of inhibiting both of these calcium dependent proteases, also is found within the muscle cell. In addition to the above mentioned u- and m-calpain, other proteases are found in muscle tissues, some of which are called the catheptic enzymes. These enzymes are encapsulated within the lysosome, which is a special muscle cell part. Therefore, they must be released from the lysosome to have contact with the muscle proteins. Cathepsins B and L are capable of breaking down certain muscle proteins, but they require a more acidic pH than is found in normal muscle. However, the possibility that they are involved in protein turnover still exists. An inhibitor to cathepsins, cystatin, is also located within the muscle cell.

Scientists have concluded that a very complex mechanism is involved in muscle growth. With a better understanding of this mechanism, research can be done to improve the efficiency of lean meat production. Scientists have also found that different muscles grow at different rates depending on their function in the body. Therefore, they suspect that those proteases or enzymes involved in muscle growth would change in relation to the growth of individual muscles.

This report summarizes results from an experiment which was designed to determine these protease activities during different stages of growth in lambs to see if a relationship exists between muscle growth and protease activity.

Procedure

Twenty-four Synthetic I (½ Finn, ¼ Rambouillet, ¼ Dorset) lambs were slaughtered, six each at 0, 8, 16 and 24 weeks of age. Samples from three different muscles (gluteus medius, longissimus and supraspinatus) were obtained immediately after slaughter to determine the activities of proteases u- and m-calpain, and their inhibitor calpastatin, and proteases cathepsin B and B + L, and their inhibitor cystatin.

Results

The effects of age on muscle weight and the activities of cathepsins B and B + L, cystatin, u- and m-calpain and calpastatin are summarized in Table 1 for each muscle. As expected, muscle weight increased as the animal's age increased from birth to 24 weeks old. In agreement, the protein content in the muscle increased significantly with the age of the animal, and differences were observed among the three different muscles. However, in the supraspinatus muscle the amount of protein per pound of muscle was not significantly different at different animal ages, but was different for the other two muscles. This implies that in the supraspinatus muscle, less protein was being deposited over time which is reflected in the muscle weights.

There were no differences among the three muscles for cathepsins B and B + L or cystatin (their inhibitor) activity. However, there were age differences within each muscle. For the gluteus medius muscle, as animal age increased from birth to 8 weeks old, cathepsin B activity decreased. At 16 and 24 weeks of age, cathepsin B activity was less than at 0 and at 8 weeks old. However, in the longissimus and supraspinatus muscles no differences were observed in cathepsin B activity at 8, 16 and 24 weeks of age, but the activity of these enzymes was greater at birth than at the other ages. Levels of cathepsins B + L activity were greater at birth than either at 8, 16 or 24 weeks of age for all three muscles. In addition, no differences were seen between 16 and 24 weeks with the activity at 8 weeks being intermediate. There was less cystatin at birth than at any of the other age times with no differences among 8, 16 and 24 weeks for the longissimus and supraspinatus muscles. However, in the gluteus medius muscle, there was less cystatin at 24 weeks than at 8 weeks. From this data, there certainly appear to be some drastic differences in the cathepsin activity in the newborn lambs when compared to older animals. We don't fully understand this finding at this time. Sometime before 8 weeks old, cathepsins B and B + L activities decreased as well as cystatin levels increased. Therefore, there seems to be a possible relationship with their activity and muscle growth, in which less enzyme activity means less protein breakdown, which would ultimately result in more protein deposited as muscle tissue. However, no difference in cathepsins B + L activity was observed between 16 and 24 weeks of age for all muscles and in cathepsin B activity and cystatin among 8, 16 and 24 weeks for the longissimus and supraspinatus muscles. Therefore, the role they play in muscle growth is still not clear.

Significant differences among the muscles for u- and m-calpain and calpastatin activities were observed (Table 1). However, the relationship with animal age appears to be similar within each muscle. For all three muscles, u-calpain activity tended to be lower at 8 weeks of age. In the gluteus medius and longissimus muscle, u-calpain activity was greater at birth and 16 weeks of age, and no significant differences were observed among 0, 16 and 24 weeks of age in the supraspinatus muscle. Activity of m-calpain was significantly higher at birth than at all other ages in all muscles, which also was observed for cathepsins B and B + L. No real pattern is evident for the other age times.

Calpastatin activity was the greatest at 16 weeks of age for all muscles. In addition, at 8 weeks of age its activity was significantly greater than at 0 and 24 weeks of age for the gluteus medius and supraspinatus muscles and the same trend was observed for the longissimus muscle. If more of the calpain activity is inhibited by calpastatin, then it would be reasonable to conclude less protein is being degraded so an increase in muscle mass can occur. Since there was a dramatic increase in calpastatin activity up to 16 weeks of

[1]Whipple is a research associate and Koohmaraie is a research physiologist, Meats Research Unit.

age, followed by a decline, it seems logical that the high calpastatin activity allowed more protein to be deposited. Then by approximately 24 weeks age the animal has reached a point in growth where emphasis is put on the depositing of fat tissue instead of lean tissue.

These results suggest that calpastatin is more of a regulator of muscle growth than any of the other proteases or inhibitors measured in this study. In addition, other research in our labs has shown the importance of calpastatin activity in the protein breakdown that occurs after slaughter which is highly related to meat tenderness. More research is planned to monitor calpastatin activity to more fully understand its role and function in animal growth.

TABLE 1—The effect of age on muscle weight, Cathepsins B and B + L, Cystatin, u- and m-Calpain and Calpastatin activities by muscle.

Age (wk)	Muscle wt. (lb)	Total protein (oz)	Cathepsin B	Cathepsin B + L	Cystatin	u-Calpain	m-Calpain	Calpastatin
Gluteus medius muscle								
0	.02^a	.01^a	389^a	289^a	.8^a	1.3^a	2.1^a	2.0^a
8	.18^b	.12^b	94^b	189^b	2.0^b	.6^b	1.0^b	3.1^b
16	.33^c	.22^c	55^c	97^c	1.8^{bd}	1.4^a	1.3^c	5.7^c
24	.53^d	.44^d	72^c	113^c	1.6^{cd}	.8^b	1.1^{bc}	1.8^a
Longissimus muscle								
0	.04^a	.03^a	412^a	310^a	.8^a	1.6^a	2.7^a	2.9^{ab}
8	.39^b	.27^b	89^b	186^b	2.1^b	.8^b	1.3^{bc}	3.4^b
16	.73^c	.51^c	53^b	103^c	2.0^b	1.4^a	1.5^b	5.8^c
24	1.15^d	.98^d	68^b	129^c	1.9^b	1.0^b	1.0^c	2.5^a
Supraspinatus muscle								
0	.02^a	.01^a	319^a	252^a	.8^a	1.3^{ab}	2.2^a	2.6^a
8	.11^b	.06^b	91^b	169^b	1.9^b	1.0^a	1.2^b	3.8^b
16	.17^c	.08^c	60^b	100^c	1.7^b	1.7^b	1.3^b	6.3^c
24	.26^d	.16^d	71^b	103^c	1.5^b	1.5^b	1.5^b	2.6^a

^{a,b,c,d}Means within each muscle without a common superscript are significantly different P < .05).

The Effect of Muscle Type on Enzyme Activity and Protein Degradation After Slaughter

Georgianna Whipple and Mohammad Koohmaraie[1]

Introduction

Meat tenderness is a trait that has received a lot of attention due to its importance in consumer acceptability. Within the last few years, consumers have become more diet conscious and have shown a growing concern about fat content in meat. Because of this recent concern, livestock producers have come under pressure to produce leaner animals. However, with the selection of leaner animals there may be a threat of producing less tender meat which could be detrimental to consumer acceptance. Therefore, the objectives of this study were to evaluate the amount of protein breakdown occurring during the aging of meat in three different muscles and to relate these changes to certain muscle enzyme(s) activity. This measure of the amount of muscle protein breakdown is highly associated with meat tenderness.

Procedure

Six Synthetic I (½ Finn, ¼ Rambouillet, ¼ Dorset) wether lambs were slaughtered at 6 months of age. Twenty-four hours after slaughter, samples were taken from the longissimus, gluteus medius and supraspinatus muscles to determine the extent of muscle protein breakdown, cathepsins B and B + L, cystatin, u- and m-calpain and calpastatin activities. The characteristics of these enzymes are discussed in the previous report. Loin chops were vacuum packaged for 6 days. Samples then were taken from the chops to determine the effect of aging on muscle protein breakdown, in which a larger mathematical value indicates how tender the meat is expected to be.

Results

There were significant differences among the three muscles at day 1 in the amount of protein breakdown, such that the longissimus muscle had the highest value followed by the values for the gluteus medius and supraspinatus muscles (Table 1). However, by day 7 the longissimus and gluteus medius muscles had similar values for the amount of protein breakdown, whereas the supraspinatus still had the lowest value. This data indicates that the longissimus muscle underwent more extensive muscle protein degradation with 1 day of post-slaughter storage, which suggests it should be the most tender. With 7 days of storage, the gluteus medius muscle had the greatest improvement in the amount of protein breakdown, such that it did not differ from the longissimus muscle at 7 days. Because the supraspinatus muscle had the lowest values at both day 1 and day 7, it should be the least tender.

As for the catheptic enzyme activity at 24 hours in the different muscles, there were no significant differences in cathepsin B activity among the muscles. However, differences were observed for cathepsins B + L activity, such that the longissimus muscle had the greatest activity compared to the other two muscles. Also, the longissimus and gluteus medius muscles had greater cystatin levels than did the su-

TABLE 1—The effect of muscle type on Cathepsins B and B + L, Cystatin, u- and m-Calpain and Calpastatin 24 h activities and the extent of post-slaughter muscle protein breakdown.

Measure of protein breakdown[a]	Muscle		
	Longissimus	Gluteus medius	Supraspinatus
day 1	52[b]	39[c]	30[d]
day 7	87[b]	86[b]	64[c]
Cathepsin B	66	61	73
Cathepsin B + L	110[b]	77[c]	82[c]
Cystatin	1.8[b]	1.6[b]	1.2[c]
u-Calpain	.3[c]	.4[c]	.7[b]
m-Calpain	1.6	1.6	1.8
Calpastatin	2.1	2.2	2.5

[a]The greater the value the more tender the meat is expected to be.
[b,c,d]Means within a row without a common superscript are significantly different (P < .05).

praspinatus muscle. If these catheptic enzymes are involved with the muscle protein breakdown after slaughter, it does not seem logical that the two muscles that had the greatest amount of protein degradation would have more cystatin which is an inhibitor to these catheptic enzymes. Though the longissimus muscle had more cathepsins B + L activity, this was not true for the gluteus medius muscle which actually had the least amount of activity and the greatest improvement in its protein breakdown value with 7 days of storage. Therefore, it appears that the catheptic enzymes have a very small role, if any, in the tenderizing of meat with normal cooler storage.

The 24 hour activities of m-calpain and calpastatin were not significantly different among the three muscles. However, the 24 hour activity of u-calpain was the greatest in the supraspinatus muscle which had the least amount of protein breakdown. Though not statistically significant, this muscle also had the highest calpastatin activity. These results indicate that in the supraspinatus muscle, a muscle in which less protein breakdown occurred, less u-calpain was utilized to degrade the proteins. This could be due to the greater amount of calpastatin (inhibitor) activity that was present, or that the u-calpain did not have access to the muscle proteins which would have prevented it from breaking them down.

In addition, other research in our laboratory has shown the importance of calpastatin activity in the improvement of meat tenderness. We do not know the reasons why different muscles have different rates of protein breakdown during post-slaughter storage affecting meat tenderness. More research to characterize these different muscles should be done to answer this question.

A Procedure for Measuring Muscle Enzymes From a Skeletal Muscle Biopsy

Tommy L. Wheeler and Mohammad Koohmaraie[1]

Introduction

Many researchers are studying postmortem tenderization of meat and how muscle proteins change, with special interest in the role of two muscle protease (enzyme) systems (calcium-dependent proteases [CDP] and lysosomal cysteine proteinases). The current procedures for understanding the activities of proteases within the muscle require separate muscle samples for the calcium-dependent protease system and the lysosomal cathepsins. In addition, the calcium-dependent protease research procedure currently requires the sacrifice of the animal in order to obtain the muscle samples.

The ability to determine activities of the calcium-dependent protease and cathepsin enzyme systems on a small muscle biopsy from a live animal would be very helpful in determining the role of these enzyme systems in muscle growth and the relative postmortem tenderization of meat. This procedure may also be useful in developing a way to predict meat tenderness in a live animal based on activity of the proteases within the muscles.

The objective of this study was to develop a procedure for measuring both the calcium-dependent and cathepsin protease systems from a single, .2-oz muscle biopsy sample from a live animal.

Procedure

Sample size Two Dorset ewe lambs (8 months of age, 110 pounds) were slaughtered and longissimus muscle samples (trimmed of connective tissue and fat) were removed from each within 15 minutes. The muscle was ground once (.13 inch plate), mixed and randomly divided into: 1) eight 2-oz samples for standard calcium-dependent protease, 2) eight .2-oz samples for standard cathepsins and 3) eight .2-oz samples for simultaneous extraction of calcium-dependent proteases and cathepsins. This phase of the study was conducted to determine whether the proteases could be measured from a biopsy-size sample (.2 oz) and whether calcium-dependent protease and cathepsin proteases could be measured on the same sample. This was a comparison of our standard procedures (evaluating large samples in separate procedures for each enzyme) and a modified procedure evaluating the biopsy-size sample for all enzymes at once.

Location effect This phase of the study was conducted to determine if the biopsy location within the muscle would affect the amount of enzyme activity measured. Three crossbred (¼ Hereford, ¼ Angus, ¼ Pinzgauer and ¼ Red Poll) steers (990 lb, 12 mo of age) were slaughtered and .2 oz of longissimus muscle was removed within 30 minutes after death from each of six locations from each side. Two sites each were located parallel to the 12th rib (anterior), the 2nd (medial) and the 4th (posterior) lumbar vertebra. At each of these sites, two samples were removed: 1) one-third (dorsal), and 2) two-thirds (ventral) the distance across the longissimus muscle from the vertebra. From each of these samples, the calcium-dependent protease system components and cathepsins B and B + L were quantified.

Biopsy samples The last phase of this study was conducted to determine if enzyme activities could be accurately measured on an actual muscle biopsy sample. Fifteen crossbred (¼ Hereford, ¼ Angus, ¼ Pinzgauer and ¼ Red Poll) steers weighing 450 lb were biopsied. A .2-oz longissimus muscle sample from the first lumbar vertebra region was removed surgically after regional anesthesia of the area was administered to the animal.

Table 1—Activities of the calcium-dependent protease (CDP) system and Cathepsins B and B + L from standard and modified procedures

	Sheep		Beef
	Standard	Modified	Biopsy sample[a]
CDP-I[b]	1.16	1.08	1.13
CDP-II[c]	.89	1.03	1.05
CDP inhibitor[d]	2.34	2.32	4.15
Cathepsin B[e]	76.6	98.8	36.3
Cathepsin B + L[e]	202.0[h]	309.8[g]	187.0
Cystatin[f]	3.44	3.19	4.3

[a]Biopsies were removed from longissimus muscle after proximal lumbar paravertebral anesthesia
[b]Low-Calcium-requiring CDP.
[c]High-Calcium-requiring CDP.
[d]Inhibition of casein hydrolysis by CDP-II.
[e]nmole product released • min^{-1} • g muscle^{-1}.
[f]Inhibitor of cathepsin enzymes.
[g,h]Means within a row with different superscripts differ (P < .05).

Results

Comparison of procedures A comparison of the standard procedures with the new modified procedure is shown in Table 1. There was no difference in the activities of any component of the calcium-dependent protease system between procedures (Table 1). There were also no differences in the activities of cathepsin B or cystatin-like inhibition. However, the modified procedure resulted in greater cathepsin B + L activity. This may not be a real effect, however, since the B + L activity from beef (Table 2) is more like the standard procedure.

Comparison of sample location The .2-oz sample used in the modified procedure might not represent the whole muscle. There could be a variation in enzyme activity in different parts of the muscle such that measured activity depends on the location within the muscle from which the sample is taken. However, the data in Table 2 indicate that the sample location within the longissimus muscle (varied either along the length or across the muscle) had no effect on activities of either the calcium-dependent protease system or the cathepsins measured.

Biopsy samples The application of the new modified procedure to muscle samples removed by biopsy was successful (Table 1). The activities of both protease systems determined from biopsies were very similar to activities from samples taken immediately after death (Table 2). These data establish the validity of using this modified procedure to quantify muscle protease activities from a muscle biopsy from a live animal.

The ability to quantify both these types of proteases from

[1]Wheeler is a research food technologist and Koohmaraie is a research physiologist, Meats Research Unit.

Table 2—Effect of location within the longissimus muscle on the activities of the Calcium dependent protease (CDP) system and Cathepsins B and B + L

| | CDP-I[a] | CDP-II[b] | CDP inhibitor[c] | Cathepsins | | |
				Cathepsin B[d]	B + L[d]	Cystatin[e]
Vertical						
Anterior[f]	1.08	1.08	3.52	32.5	231.3	3.85
Medial[g]	1.09	1.03	3.68	32.7	246.9	3.80
Posterior[h]	1.03	1.06	3.49	32.4	235.6	3.39
Horizontal						
Dorsal[i]	1.06	1.04	3.65	33.1	234.5	3.69
Ventral[j]	1.08	1.07	3.50	32.0	241.3	3.67

[a]Low-Calcium-requiring CDP.
[b]High-Calcium-requiring CDP.
[c]Inhibition of casein hydrolysis by CDP-II.
[d]nmole of product released $\cdot$ min^{-1} $\cdot$ g muscle^{-1}.
[e]Inhibitor of cathepsin enzymes.
[f]Located parallel to the 12th rib.
[g]Located parallel to the 2nd lumbar vertebra.
[h]Located parallel to the 4th lumbar vertebra.
[i]Located one-third across the longissimus muscle from the vertebrae.
[j]Located two-thirds across the longissimus muscle from the vertebrae

a single, .2-oz biopsy sample should be very useful in attempts to characterize the role of these proteases in muscle protein turnover and postmortem tenderization of meat. It is now possible to monitor the activities of these proteases in the same animal at different stages of growth from biopsied samples. In addition, this procedure may be useful in developing a way to predict meat tenderness in the live animal.

The importance of calcium-dependent protease inhibitor in the postmortem proteolysis and subsequent tenderization of meat has been established and mathematical equations for predicting meat tenderness from protease activities within the muscle have been published. This information could be obtained from sires and progeny to estimate heritability and then used for the selection of animals with more tender meat. The protease activities and myofibril fragmentation index (MFI) (a measurement of the breakdown of muscle fibers) from a biopsy sample might be used in combination to predict meat tenderness of the live animal.

Acceleration of Postmortem Tenderization in Ovine Carcasses Through Infusion of Calcium Chloride

Mohammad Koohmaraie, John D. Crouse, Harry J. Mersmann[1]

Introduction

Scientists at MARC have been studying the mechanisms involved in meat tenderization during postmortem storage of carcasses at refrigerated temperatures, called "aging" by the industry. They have already documented that the breakdown of proteins (or proteolysis) in the muscle tissues, specifically myofibrillar proteins, is a key event in this tenderization process.

When lamb carcasses were infused with .3 molar of calcium chloride immediately after death, a definite acceleration of tenderness and breakdown by enzymes of the muscle protein structures was noted at 24 hours after death.

MARC scientists suggest that this increased tenderization factor was caused by an activation of a kind of enzyme called calcium-dependent protease. Other scientists have reported that they feel an elevation of ionic strength, which is an enhanced ion activity that results in increased protein solubility, during the postmortem storage time is what causes the tenderization of the infused meat.

This study was undertaken to better understand three things: 1) what effects different concentrations of calcium chloride would have on tenderness, 2) what effect injection of calcium chloride would have on the ionic strength in the samples and how this effects tenderness, and 3) to test the hypothesis that injection of calcium chloride causes increased tenderness in meat due to the activation of calcium-dependent proteases.

Materials and methods

Animals These experiments were conducted in two stages. In the first experiment, the effect of different concentrations of calcium chloride was examined. For this experiment, 20 lambs (8 to 12 months old, 75 to 110 pounds live weight) were slaughtered. Lambs were slaughtered in groups of five; one for each of the five treatments: 1) control (animals were slaughtered according to normal procedures); 2) electrically stimulated immediately after death (2 Hz; 100 volts; total of 360 pulses; 10 seconds on, 10 seconds off); 3) electrically stimulated and then infused with a volume equal to 10% of the liveweight of .075 molar calcium chloride; 4) same as Treatment 3 but with .15 molar calcium chloride; and 5) same as Treatment 3 but with .3 molar calcium chloride.

The second experiment was conducted to study the effect of ionic strength on the increased tenderness that results from the calcium chloride infusion of ovine carcasses. For this experiment 18 lambs (8 to 12 months old, 79 to 110 pounds liveweight) were slaughtered. Lambs were slaughtered in groups of three, one for each of three treatments: 1) electrically stimulated, as indicated above; 2) electrically stimulated and then infused with sodium chloride and 3) electrically stimulated and then infused with calcium chloride. Because the objective of this experiment was to study the effect of ionic strength, sodium chloride and calcium chloride solutions were used at the same ionic strength. A .3 molar solution of calcium chloride was used because in the first experiment .3 molar was found to be the most effective concentration of calcium chloride to increase tenderness measured at 24 hours postmortem. The conductivity of .3 molar calcium chloride solution was measured by a conductivity meter in order to obtain the ionic strength. A concentration of sodium chloride (.6 molar) that gave the same conductivity reading was prepared and used during this experiment.

Infusion and Sampling After completing the electrical stimulation, the lamb carcasses were transferred to a lamb cradle and the carotid artery was brought to the surface. Solutions were pumped into the artery with a pumping device (during the infusion process, one jugular vein remained intact and the other was opened. The carotid artery not used for infusion was clamped). After completion of the infusion, the carcasses were dressed and transferred to a holding cooler (33 to 35° F). Twenty-four hours after slaughter, the entire loin was removed and divided into two sections and assigned to either 1 day or 7 days postmortem to find the following: day 1: shear force (a mechanical evaluation of tenderness), activities of two forms of calcium-dependent protease (-I, -II) and an enzyme that inhibits their performance, and mineral analysis (calcium and sodium content); and at day 7: shear force.

Table 1—Effect of treatments on pH, calcium content, shear forces and enzyme activities in ovine longissimus muscle

Traits	Control	ES[a]	ES + .075 molar calcium chloride	ES + .15 molar calcium chloride	ES + .3 molar calcium chloride
Calcium, ppm	3.5[f]	4.0[f]	132.3[g]	214.8[g]	553.2[h]
Shear force, day 1[b]	22.7[f]	19.0[f,g]	18.6[g]	13.6[h]	7.5[i]
Shear force, day 6[b]	19.0[f]	12.0[g]	13.4[g]	10.3[g,h]	6.5[h]
CDP-I[c]	37.8[f]	37.0[f]	29.5[f]	7.9[g]	0[g]
CDP-II[d]	70.2[f]	77.9[f]	70.5[f]	65.1[f]	18.2[g]
CDP-inhibitor[e]	47.1[f]	48.0[f]	55.5[f]	50.8[f]	0[g]

[a]Electrically stimulated.
[b]lb / ½ inch.
[c]Low calcium-requiring calcium-dependent protease total activity/0.22 lb muscle (caseinolytic activity).
[d]High calcium-requiring calcium-dependent protease total activity/0.22 lb muscle (caseinolytic activity).
[e]Inhibitor of CDP-I and CDP-II, A_{278}/0.22 lb muscle (inhibition of casein hydrolysis by CDP-II).
[f,g,h,i]Means within the same row with different superscripts differ (P < .05).

Shear Force (mechanical tenderness evaluation) Determination Shear force of the cooked chops was determined after 1 and 7 days of cooler aging.

Calcium and Sodium Determination Water-extractable calcium and sodium content of longissimus muscle were determined by a standard scientific technique called atomic absorption.

Preparation of Calcium-Dependent Proteases and Their Inhibitor Low and high calcium-requiring forms of calcium-dependent protease (CDP-I and CDP-II, respectively) and their inhibitor (CDP-inhibitor) were prepared from 0.22 lb of longissimus muscle at 24 hours postmortem.

Results and Discussion

As we have previously reported, infusion of lamb carcasses with .3 molar calcium chloride increased the tenderness of day 1 carcasses dramatically compared with control carcasses or carcasses that were electrically stimulated but not infused (Table1). Infusion of carcasses with .075 molar calcium chloride had no effect on tenderness, but infusion of .15 molar calcium chloride increased tenderness by a decreased shear force of 5.5 lb compared to the carcasses that were electrically stimulated but not infused.

Activities of calcium-dependent protease-I, calcium-dependent protease-II and their inhibitor at 24 hours postmortem were similar for the control carcasses, electrically stimulated and carcasses infused with .075 molar calcium chloride (Table 1). Carcasses infused with .15 molar calcium chloride had lower calcium-dependent protease-1 activities (lower protease activity indicates that the self-destructing proteases have been activated to such a point that they degrade themselves) than controls; there was no calcium-dependent protease-I activity remaining in the carcasses infused with .3 molar calcium chloride. The calcium-dependent protease-II activity and inhibitor activity were lowered only in carcasses infused with .3 molar calcium chloride.

When carcasses were infused with .075 molar calcium chloride the amount of water-extractable calcium (assumed to be free calcium) in longissimus muscle was about 132 parts per million (ppm) of tissue (Table 1). This amount of free calcium corresponds to 3.3 millimolar of calcium distributed naturally in the muscle. This concentration should have been sufficient to activate both calcium-dependent protease-I and calcium-dependent protease-II; yet, no tenderization effect was observed, nor was there any effect on calcium-dependent protease-I, -II or their inhibitor. Assuming that this tenderization is achieved through activation of calcium-dependent proteases, then most of the calcium found in the muscle after infusion of .075 molar calcium chloride must be structured differently from calcium-dependent protease-I or calcium-dependent protease-II, so that neither of these enzymes was activated to produce tenderization.

The effect of these treatments on the inhibitor of calcium dependent protease is interesting. It has been demonstrated that both calcium-dependent protease-I and calcium-dependent protease-II can override the specific inhibitor of this protease system in a test tube. The infusion of carcasses with .15 molar calcium chloride caused a dramatic decrease in calcium-dependent protease-I activity but not in calcium-dependent protease-II or the inhibitor activities. However, when .3 molar calcium chloride was infused calcium-dependent protease-II activity was enhanced (as evidenced by loss of enzyme activity due to autolysis) and no inhibitor activity could be detected. Again, the inhibitor of the calcium-dependent protease system was affected only when calcium-dependent protease-II was activated. These results suggest that calcium-dependent protease-II and the inhibitor might be located in a different part of the skeletal muscle cell than calcium-dependent protease-I.

Ionic Strength On the basis of test tube (in vitro) experiments, other investigators have suggested that elevation of ionic strength in muscle during postmortem storage is one of the reasons for the observed tenderization of meat during this time. Because of high ionic strength of the infusion solution (.3 molar calcium chloride), a treatment that included infusion of carcasses with sodium chloride at the same ionic strength as the calcium chloride solution was included. The conductivity of a .3 molar calcium chloride solution was determined, and the sodium chloride solution for infusion was prepared to have the same conductivity (.6 molar sodium chloride). Results indicated that infusion of ovine carcasses with .6 molar sodium chloride did not increase tenderness at day 1 as was found in carcasses infused with calcium chloride (Table 2). However, the aging response (increase in tenderness between the 1st day and the 6th day postmortem) was much higher in sodium chloride-infused carcasses than in control carcasses. Therefore, it appears that elevation of ionic strength during postmortem storage could possibly contribute to the tenderization process. However, our results seem to indicate that acceleration of postmortem tenderization (by day 1) due to infusion of calcium chloride is not the result of an increase in ionic strength, because the tenderization process in calcium chloride-infused animals already had occurred by 1 day postmortem. We suggest that the observed tenderization is due to activation of the calcium-dependent proteases.

In summary, the results of these experiments indicated that infusion of carcasses with calcium chloride is an effective method of accelerating postmortem tenderization, such that cooler aging is not necessary to assure tenderness of meat. Results also indicated that calcium chloride acts by activating naturally occurring enzymes.

Table 2—Effect of treatments on sodium, calcium content, shear forces and enzyme activities in ovine longissimus muscle

Traits	Treatments		
	ES[a]	ES + sodium chloride	ES + calcium chloride
Sodium, ppm	527.7[c]	2491.2[d]	588.6[c]
Calcium, ppm	7.6[c]	6.5[d]	505.2[d]
Shear force, day 1[b]	19.5[c]	17.6[c]	9.7[d]
Shear force, day 7[b]	13.8[c]	8.4[d]	8.9[d]
Calcium dependent protease-I[b]	59.1[c]	55.0[c]	0[d]
Calcium dependent protease-II[b]	78.1[c]	77.2[c]	41.2[d]
Calcium dependent protease-inhibitor[b]	78.1[c]	70.6[c]	22.8[d]

[a]Electrically stimulated.
[b]See Table 1 for abbreviations.
[c,d]Means within the same row with different superscripts differ ($P < .05$).

Methodology for Predicting Meat Tenderness from Live Animals

John D. Crouse and Mohammad Koohmaraie[1]

Introduction

The objective of this research was to develop a way to predict tenderness of meat from live animals. The consistency of muscle fibers in meat samples obtained immediately after death in a way that simulated our muscle biopsy sampling procedures was compared with the consistency of muscle fibers in meat samples obtained after postmortem aging. These samples were also compared to a mechanical (shear force) testing of aged, cooked meat for tenderness.

Our work has shown that aging of meat is primarily responsible for variations in tenderness of meat. The myofibril fragmentation index is a measurement procedure to determine the consistency of muscle fibers and how they break down in aging. It, therefore, can measure the amount of aging a muscle has undergone, and has been shown to be highly correlated with tenderness and mechanical shear force testing of steaks for tenderness. In a previous study, meat samples .5 inch in diameter and 1.0 inch in length obtained from steaks were used for the myofibril fragmentation index determinations. Samples of similar size could be obtained through muscle biopsy techniques to make myofibril fragmentation index observations. However, the biopsy samples would have to be aged to be able to compare them to myofibril fragmentation index or mechanical shear force observations of aged meat. Researchers do not know what effect obtaining core samples by muscle biopsy techniques will have on the postmortem aging processes of the samples and their resulting myofibril fragmentation index values.

Procedure

Twelve market weight wether lamb carcasses (USDA Choice) were used. Meat core samples from the rib eye muscle of one side of the carcass were taken immediately after death to simulate muscle biopsy procedures. Meat core samples were obtained using a .5 inch by 1.5 inch coring device driven by an electric drill. Difficulty was encountered in obtaining cores of uniform size and weight from the warm, soft muscle tissue immediately after slaughter. Therefore, about 12 to 15 cores, weighing about .07 ounces each, were obtained from between the 5th rib and the 4th lumbar vertebra and made into 4 or 5 samples. Samples were vacuum packaged and aged in the cooler with the intact carcasses.

Carcasses were aged 7, 8, 9 or 10 days postmortem in a 34o cooler. After 7 days, 2 carcasses were selected randomly and 1-inch chops obtained from the longissimus muscle between the 5th rib and 3rd lumbar vertebra from sides opposite to the sides from which the cores were taken at slaughter. Four alternate chops were assigned to mechanical shear force evaluation and 3 alternate chops were cored twice for myofibril fragmentation index (MFI) analysis. The same sampling procedure was used on carcasses from days 8, 9, and 10. Chops obtained for mechanical shear testing were frozen at -20oF for subsequent cooking.

The myofibril fragmentation index analyses were conducted on cores which were removed from the carcass at slaughter and then aged (MFIO), and cores that were taken from the same carcasses after the carcass was aged.

Chops were prepared for mechanical shear force observations following guidelines of the American Meat Science Association. Frozen chops were allowed to thaw for 24 hours

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Table 1 – Averages and standard deviations for myofibril fragmentation index by time of coring and shear force

| | Time of Coring | | | | |
| Biopsy[a] | | Carcass[a] | | Shear force | |
Ave.	SD	Ave.	SD	Ave.	SD
69.18	7.04	81.38	9.03	4.23	1.47

[a]Absorbance per 0.5 mg myofibril protein x 200.

at 33° to 34°F and then broiled. Meat internal temperature was mechanically monitored during cooking. Chops were turned at 104°F and removed from the broiler at 158°F. Chops were stored in ventilated polyethylene bags for 24 hours at 34° to 40°F before coring. Cores .5 inch in diameter were cut such that the fiber direction of the muscle was parallel to the length of the core. Cores were mechanically sheared with an Instron Testing Instrument equipped with a Warner-Bratzler shear blade.

Results

Results by the averages and standard differences from the average are given in Table 1 for the Biopsy Sample, the Carcass Sample and the shear force determined tenderness. The differences for shear force determined tenderness indicated considerable variation existed among the 12 carcasses for shear force determined tenderness. The differences in variations found in the myofibril fragmentation index values for biopsy or carcass treatments were similar and were 10 or 11%, respectively. However, the values for myofibril fragmentation index were less for the biopsy treatment than for the carcass treatment. The myofibril fragmentation index procedure basically reflects the degree of proteolysis (breakdown of muscle tissues) that muscle fibers undergo that is associated with aging. Evidently, the muscle fibers that were aged after the muscle biopsy underwent less proteolysis than myofibrils aged in the intact muscle.

The data variations in the biopsy were closely related to data variations in the carcass treatment. Shear force evaluated tenderness between the biopsy and carcass treatments was also similar. The myofibril fragmentation index of the biopsy cores was closely related to the shear force indicated tenderness of the meat, and comparable to the carcass treatment data.

Evidently, the method of aging, biopsy sample core vs. intact muscle, had no effect on the relationship of myofibril fragmentation index with shear force testing for tenderness.

Results of the work reported here indicated that myofibril fragmentation index is a method that was useful for predicting shear force determined tenderness; it should also be useful in evaluating muscle samples obtained by biopsy techniques for estimating mechanical shear or human sensory panel evaluated tenderness. This technique would be very useful in live animal selection projects or feeding trials to monitor changes in meat characteristics.

Table 2 – Regression equations that estimate shear force by myofibril fragmentation index samples obtained at slaughter or after aging

| | Independent variable regression coefficient | | | |
Intercept	Aging postmortem	Biopsy	Carcass	R^2
11.6	− 0.87			0.34
19.3	− 0.97	0.10		0.56
18.0	− 0.86		0.08	0.58

Improvement of Warmed-over Flavor and Tenderness

Allen J. St. Angelo, Mohammad Koohmaraie, Karen L. Crippen, John D. Crouse[1]

Introduction

We have shown recently that infusion of lamb carcasses with .3 molars (about 44.5 grams per liter) calcium chloride resulted in acceleration of postmortem tenderization. We concluded that the observed postmortem breakdown of proteins and resulting tenderization was due to activation of calcium-dependent proteases, and not due to the ionic strength of the calcium chloride solution. While the work was being done, scientists at the Southern Regional Research Center of the Agricultural Research Service, New Orleans, LA, have been engaged in an in-depth study of the cause and development of warmed-over flavor in meat. Warmed-over flavor is described as the rapid development of an oxidized flavor in refrigerated cooked meat during storage. The flavor characteristics were originally described as rancid or stale. However, the Southern Regional Research Center group has shown that warmed-over flavor is a combination of increase in the off-flavor characteristic noted with a following decrease in the desirable meaty flavor characteristics.

In 1987, combined efforts by scientists at both centers identified compounds that would dissolve in .3 molars calcium chloride, would not bind or chemically alter the calcium, would retain desirable flavor characteristics and retard warmed-over flavor development. To this end, many compounds previously known to be active antioxidants for preventing warmed-over flavor were screened for solubility in .3 molars calcium chloride. Three of these, maltol, kojic acid and sodium ascorbate (vitamin C), were completely soluble. Because the experimentally treated samples would eventually be evaluated by a trained sensory panel, maltol and vitamin C were the antioxidants chosen for the experiments. Kojic acid was not used since it is neither on the Generally Regarded As Safe list nor FDA approved as a food additive.

Procedure

For these experiments, a series of 25 lambs was slaughtered at MARC in groups of five, a group for each of the five treatments, which included the following: 1) no treatment (animals slaughtered by normal procedures); 2) control (electrically stimulated immediately after death); 3) electrically stimulated and then infused with a volume equal to 10% of the liveweight of .3 molars calcium chloride ($CaCl_2$); 4) same as Treatment 3 but with .25% maltol added; 5) same as Treatment 3 but with 1.0% vitamin C added.

Immediately after slaughter, lamb carcasses were transferred to a lamb cradle, the carotid artery was exteriorized, and solutions were pumped into the artery. The carcasses were dressed and transferred to a holding cooler (33-36°F). Twenty-four hours after slaughter, the entire loin was removed. Some of the loin samples were ground twice, frozen and sent by air express to Southern Regional Research Center for evaluation by chemical, instrumental and sensory means.

An in-house analytical sensory panel of 16 members was trained for descriptive analyses of lamb samples using ground lamb patties, freshly cooked and cooked/stored in the refrigerator for up to 3 days to develop the list of descriptive terms. The list of descriptive terms included the following: meaty (the flavor associated with cooked muscle meat, such as beef), gamey or muttony (the flavor associated with muscle meat from wild game or from older lambs), musty/herby (associated with wet soil or mulch and dried herbs, such as rosemary or thyme), browned/caramel (associated with the outside of grilled or broiled lamb, seared, but not burnt), grainy or cowy (associated with cow meat and/or meat in which grain or feed character is detectable), bloody/serum associated with raw lean meat), livery (associated with organ meats such as liver), fatty (associated with cooked lamb fat), painty (similar to linseed oil and associated with rancid fat or oil), and cardboardy (similar to wet cardboard and associated with refrigerated cooked meat). The four basic tastes were also used. These were: sweet (taste on the tongue as with sugars), sour (as with acids), bitter (as with bitter agents such as caffeine or quinine), and salty (as with sodium ions). The descriptor, astringent (the chemical feeling factor on the tongue described as puckering or dry and as with tannin or alum) was also used in this study.

In preparation for a sensory panel session on patties made from the 5 sets of treated lamb prototypes, half of the ground experimental samples were removed from the freezer and allowed to thaw overnight at 38°F. The next morning, they were made into 2.8-oz patties, cooked and stored in glass Petri plates at 38o F for 2 days at which time they were rewarmed and evaluated. The day prior to the panel session, the remaining half was removed from the freezer and allowed to thaw overnight at 38° F. The next morning, the samples were made into 2.8-oz patties, cooked, and assayed as day zero samples. Sensory scores were presented as intensity values on a 15 point scale with 0 indicating the lowest intensity and 15 the highest. All panel members were able to distinguish the lamb descriptors at a very high degree of proficiency and reproducibility.

The effect of different treatments on lamb samples was evaluated chemically by determining the 1) TBARS numbers (2-thiobarbituric acid reactive substances; a measure of oxidation), and 2) by the direct gas chromatographic method, a standard scientific measuring method.

Results

Results indicated that the mechanical shear force testing values for tenderness of electrically stimulated carcasses were not significantly different from those of the non-electrically stimulated. Mechanical shear force tenderness values of carcasses infused with calcium chloride were significantly reduced when compared to control lambs. A lower shear force value indicates increased tenderness in the meat. Thus, tenderization was significantly increased by calcium chloride infusion. On adding either maltol or vitamin C to the infusion medium, no differences were observed in shear force from those of carcasses infused with calcium. Therefore, the effect of calcium ions on breakdown of enzymes and tenderization of lamb carcasses was not impeded by maltol or vitamin C.

At 0 and 2 days of storage, lipid oxidation for the control and treated lambs was essentially the same. When calcium chloride solution was infused, the averages doubled, which suggested that the highly significant differences observed

were due to an increase in lipid oxidation catalyzed by the calcium. When maltol was added to the calcium chloride solution, the measures of oxidation values decreased by 78% for the 0-day samples and 74% for the samples stored 2 days, compared to the group that received just calcium chloride. Similar results were observed when vitamin C was added to the calcium chloride solution. The decrease in measures of oxidation of lipids was 74% for the 0-day samples and 92% for those stored 2 days. These values were significantly less than the control samples.

Taste panel sensory score averages from the experimental samples were also recorded. Zero-day samples from lambs not infused showed highly significant differences in the warmed-over flavor descriptors, cardboardy and painty, when compared to the controls. However, no significant differences were observed among samples stored for 2 days. When calcium was infused, the warmed-over flavor sensory attributes, cardboardy and painty, increased when the patties were stored 2 days, compared to the control carcasses. During storage, differences increased by 1.76 units for cardboardy and 2.24 units for painty on a scale of 0 through 15. On the other hand, increases observed in controls were only 1.45 for cardboardy and 1.74 for painty. These observations supported the chemical data that indicated lipid oxidation was promoted by calcium chloride infusion. However, when maltol was added to the infusion mixture, the increase in 2-day storage sensory values from the calcium chloride infused samples was greatly reduced. For example, the overall net increase was only .26 for cardboardy and .33 for painty. Likewise, when vitamin C was added to the infusion mixture, the 2-day storage sensory values also were reduced when compared to the calcium infused carcasses. The net increase during storage was only .12 for cardboardy and .39 for painty.

Meaty, musty/herby and sweet were all sensory terms for desirable flavor notes. They showed a decrease of 1.01 units for meaty and .15 units on a scale of 0 through 15 for sweet, and an increase of .05 units for musty/herby in the calcium chloride infused samples. When maltol was added to the infusion solution, the meaty descriptor decreased by only .66 units but sweet taste increased .08 and musty/herby increased by .24 units. When vitamin C was added to the patties, meaty decreased by only .59, whereas sweet increased .20 units, and musty/herby increased .10 units. That is, adding maltol or vitamin C to the calcium chloride infusion mixtures not only reduced lipid oxidation, but also retained desirable flavor characteristics and diminished formation of off-flavors.

The flavor descriptors, gamey, bloody/serum, fatty, sour, browned/caramel, salty, astringent and bitter showed no significant treatment-storage interaction effect. By averaging responses from both storage times for each treatment, a significant treatment effect can be identified. With any treatment, almost all these attributes showed significant change after being stored for 2 days. When patties from calcium chloride infused animals were compared to those with added maltol, the sensory attributes with the most significant differences were browned/caramel and sour. When vitamin C was added to the calcium chloride infusion mixture, the sensory attributes with the most significant differences were bitter, fatty and salty. With maltol treated samples, browned/caramel (a desirable flavor) increased by .23 units, whereas sour (an undesirable flavor note associated with warmed-over flavor) decreased by .17 units. In samples treated with vitamin C, the flavor note, bitter, associated with warmed-over flavor, decreased by .27 units.

Conclusions

In summary, research results indicated that infusion of lamb carcasses with calcium chloride speeded up postmortem tenderization so much that storage of carcasses beyond 1 day to ensure their tenderness was not necessary. Results also indicated that calcium chloride increased lipid oxidation and warmed-over flavor development. Maltol and/or vitamin C, co-infused with the calcium chloride, was able to overcome the oxidizing effect of calcium, reduce lipid oxidation and retard the development of warmed-over flavor, but did not adversely interfere with tenderization effects of calcium chloride. Samples treated with the antioxidants (maltol and/or vitamin C) had the lowest off-flavor (painty and cardboardy) intensities while maintaining highly desirable (meaty, sweet and musty/herby) intensities. Therefore, lamb carcasses treated with both calcium chloride and antioxidants were not only more tender, but patties made from them had more desirable flavor.

Comparison of a Terminal Sire Composite Population With the Suffolk Breed

Kreg A. Leymaster[1]

Introduction

Many popular sheep breeds originated from a crossbred foundation involving two or more breeds. For example, the Rambouillet and Lincoln breeds were crossed in 1912. The resulting crossbred sheep were mated among themselves in subsequent generations and the population was eventually recognized as a new breed, the Columbia. A population created from a crossbred foundation is often referred to as a composite population. The performance of a composite population is equal to the average performance of the con- tributing pure breeds, with an added "boost" from the usually favorable effect of heterosis (or hybrid vigor). Heterosis effects have a tendency to be greater for reproductive and survival traits, more than for growth and compositional traits. Because breed effects are averaged in crossbreds, and due to the effects of heterosis (or hybrid vigor), the performance of a composite population generally is different from perfor- mance of each of the contributing pure breeds. In this way, a composite population can be designed to fill an existing need of the industry.

A terminal sire composite population was formed by mating Columbia rams to Hampshire-Suffolk crossbred ewes. This population was designed to provide animals for studying genetic effects on growth, feed intake, and carcass composi- tion and how they could be combined to improve lean growth efficiency. This population was used in this study instead of a pure breed, to take advantage of the favorable effects of heterosis that are found in composite populations. Scientists reasoned that the composite population would benefit from heterosis effects while maintaining the superior breed effects of the Columbia, Hampshire, and Suffolk breeds for growth rate and carcass composition. The specific experimental objective was to compare the performance of the composite population in this study to performance of the industries' dominant terminal sire breed, the Suffolk. If the general per- formance of the composite population created in this study and the Suffolk breed is similar, then future information about lean growth efficiency gathered on the composite population should be pertinent to other terminal sire breeds as well.

Procedure

The first generation (F_1) of the composite population was produced in 1980, 1981, and 1982. These lambs were sired

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by 27 Columbia rams mated to Hampshire-Suffolk crossbred ewes. The Columbia rams had been selected based on struc- tural soundness, skeletal size, and subjective appraisal of muscling. The second generation (F_2) was produced in 1981 through 1984 by mating 31 F_1 rams to F_1 ewes. The F_3 generation, born in 1982 through 1987, was produced by 27 F_2 rams.

A purebred Suffolk flock of about 500 ewes was put together by purchase of registered ewes out of seven flocks from 1966 through 1976. A total of 51 rams, selected from 23 flocks, was purchased from 1966 through 1983. The pur- chased rams were selected for similar traits as described for Columbia rams.

The productivity of 2-, 3-, 4-, and 5-year-old ewes (mature ewes) of each population was measured during two distinct lambing seasons in 1986. A total of 358 mature composite ewes, sired by 53 rams, were available. Most (74%) of these ewes were of the F_2 generation whereas the remaining ewes were of later generations. The 333 mature Suffolk ewes were sired by 71 rams. The composite ewes were exposed to 25 composite rams and the Suffolk ewes to 24 Suffolk rams. Ewes were single-sire mated and rams were used in both breeding seasons during the fall of 1985.

The ewes born in 1986 (young ewes) were exposed to lamb at a year of age during two lambing seasons in 1987. The 235 young composite ewes were of at least the F_3 genera- tion. The composite ewes and 163 young Suffolk ewes were single-sire mated to rams of their own type during the fall of 1986. The productivity of the young ewes was then deter- mined in the spring of 1987.

Composite and Suffolk sheep were managed together as a single flock during each production season. Ewes were weighed prior to breeding and left on pasture during gesta- tion with supplemental feed provided as needed. Ewes were lambed in poleshed facilities under semiconfinement condi- tions. Ram lambs were left intact and creep feed was provided to all lambs by 14 days of age. Lambs were weaned at 7 weeks of age. Data on postweaning survival and growth were collected only on ewe lambs born to mature ewes in 1986.

Ewe productivity data were analyzed to account for effects of breed, age of ewe, season, and interactions of all these effects. Lamb traits recorded up until they were weaned were also adjusted for effects of breed, season, age of dam, sex, and interactions of all these effects. Postweaning traits were measured only on ewe lambs so effects of sex could not be

Table 1—Productivity of young and mature Composite and Suffolk ewes[a]

Trait	Young ewes		Mature ewes	
	Composite	Suffolk	Composite	Suffolk
Weight at breeding, lb	103 *	106	182	182
Conception, percent	56.5	59.4	91.0	87.5
Number born alive	1.05	1.13	1.60 **	1.79
Litter birth weight, lb	12.7	12.4	20.5	20.6
Preweaning survival, percent	59.8	56.3	89.2 **	82.0
Number weaned	.62	.63	1.41	1.44
Litter weaning weight, lb				
Per ewe lambing	25.1	23.1	61.6	61.8
Per ewe joined	14.5	13.6	54.6	53.0

[a]Probability of declaring the breed difference to be significant when it is actually due to chance (* = 5%, ** = 1%).

estimated. Research results comparing composite and Suffolk populations are given in Table 1 for ewe productivity and Table 2 for lamb performance traits.

Results

Young Suffolk ewes were 3 pounds heavier than composite ewes at breeding, but weights of mature composite and Suffolk ewes were the same (Table 1). Conception rates of composite and Suffolk ewes were similar regardless of age of ewe. Although mature Suffolk ewes gave birth to more lambs than mature composite ewes, litter birth weights were alike between breeds for ewes of all ages. During the first lambing season of 1987 a severe blizzard adversely affected the survival and growth of lambs born to young ewes. Even so, there was little difference between the breeds for survival to weaning of the litters born to the young ewes. On the other hand, composite lambs born to the mature ewes had greater survival to weaning than litters born to the mature Suffolk ewes. The advantage in survival of the composite population was especially noticeable for twin-born lambs. The lower drop rate of composite ewes was offset by the greater survival of their lambs so that the number of lambs weaned per ewe lambing did not differ between breeds. Composite and Suffolk ewes produced similar litter weaning weights per ewe lambing and per ewe joined (exposed to rams). Litter weaning weight per ewe joined is a measure of overall productivity and the small advantages of the young and mature composite ewes over Suffolk ewes are not considered statistically significant by researchers.

Composite lambs were about one pound heavier at birth than Suffolk lambs regardless of the age of the dam (Table 2). As noted previously, survival of lambs born to mature composite ewes was greater than that of lambs born to mature Suffolk ewes. Daily gains to weaning were about the same for lambs born to both the mature composite and the mature Suffolk ewes, but the lambs born to the young composite ewes grew a little more rapidly to weaning than the lambs born to the young Suffolk ewes. Due to this difference, the weaning weight of lambs born to the young composite ewes was 3.5 pounds heavier than that of lambs born to the young Suffolk ewes. Composite and Suffolk lambs born to the mature ewes were about the same in weaning weight. The postweaning performance of composite and Suffolk ewe lambs did not differ for survival, daily gain, or 125-day weight.

In conclusion, the results indicated that the composite population was at least as productive as the Suffolk breed for typical performance traits. It must be pointed out, however that the most important traits for a terminal sire breed relate to male fertility and survival, growth, feed intake, and carcass composition of crossbred progeny. These traits also need to be evaluated before the composite population should be considered for use as a terminal sire breed. It is important to remember that the composite population benefits from the favorable effects of heterosis. However, when the composite is used as a terminal sire, the heterosis effects present in the composite population are not passed on to the market lambs. Therefore, the Suffolk may still be a superior terminal sire breed despite the general similarity of performance between Suffolk and composite sheep. Even so, genetic approaches designed to improve lean growth efficiency in composite sheep should be useful when used with established terminal sire breeds such as the Suffolk and Hampshire.

Table 2—Performance of Composite and Suffolk lambs born to young and mature ewes[a]

Trait	Young ewes		Mature ewes	
	Composite	Suffolk	Composite	Suffolk
Birth weight, lb	11.4 *	10.4	12.4 * *	11.4
Preweaning survival, percent	58.2	55.0	88.0 *	80.5
Preweaning daily gain, lb/day	.58	.52	.63	.64
Weight at 7 weeks (weaning), lb	39.6 *	36.1	43.7	43.0
Postweaning survival, percent[b]			95.9	91.9
Postweaning daily gain, lb/day[b]			.59	.61
Weight at 125 days, lb[b]			88.7	88.9

[a]Probability of declaring the breed difference to be significant when it is actually due to chance (* = 5%. * * = 1%).
[b]Postweaning data were collected on ewe lambs only

Comparison of Texel and Suffolk Rams as Sires of Market Lambs

Kreg A. Leymaster and Thomas G. Jenkins[1]

Introduction

An important goal of the sheep industry is to increase carcass leanness. Leanness can be improved by using terminal sires in a crossbreeding system, in order to sell the market lambs sired by these rams. Terminal sire breeds of sheep should produce superior levels of performance for male fertility and survival, growth rate, feed intake, and carcass composition of the crossbred progeny. Growth rate and carcass composition seem to have been emphasized in the United States, where the Suffolk breed is currently the dominant terminal sire breed. However, other breeds throughout the world may be comparable or even preferable to the Suffolk. Importation of promising breeds from around the world for evaluation can help us understand the usefulness of these desirable foreign breeds. Results of past experiments done in Europe that evaluated numerous terminal sire breeds have indicated that crossbred progeny of Texel rams were generally average for postweaning growth rate, but excelled in carcass compositional traits such as carcass lean, lean-to-bone ratio, and area of the longissimus muscle.

Based on the European results, we wanted to import and evaluate the Texel breed as a possible alternative terminal sire breed to the Suffolk. Texel sheep were imported from Denmark and Finland and arrived at MARC during early 1985. Details of the importation were given in an earlier MARC sheep progress report. Following establishment of the purebred flock, an experiment to evaluate the Texel breed as a terminal sire breed was conducted. The objective was to determine the difference between Texel and Suffolk rams for survival, growth, and carcass composition of crossbred progeny.

Procedure

Nineteen Texel and 20 Suffolk rams were used in the experiment. The Texel rams were the imported rams and their sons from matings with Finnish Texel ewes. Most of the Suffolk rams were purchased at test station sales based on subjective assessment of muscling. The remaining Suffolk rams were selected in a similar manner from the broadly based MARC Suffolk flock. The intent was to sample the Suffolk breed so that results applied to the commercial industry. The Texel and Suffolk rams were mated to mature, half-Finn ewes that were synchronized to give uniform lambing dates. The ewes were lambed under semiconfinement conditions, producing 325 lambs during 1988 and 1989. Ram lambs were banded and creep feed was provided by 14 days of age. Lambs were weaned at an average age of 51 days. Postweaning data were collected on 183 multiple-born, multiple-reared lambs. These lambs were weighed every four weeks and representative samples were slaughtered at 9, 15, 21, or 27 weeks of age. Carcasses were ground and chemically analyzed to measure ash, fat, water, and protein. Ash is representative of bone, whereas water and protein together are roughly the same as muscle.

Data were summarized to make up for different effects of the year, breed of sire, sex of lamb, and interactions among these effects. Traits recorded up until lambs were weaned were adjusted for effects of the type of birth, which varied from 1 to 5. Traits recorded after weaning were associated with the age of the lamb at slaughter so scientists could estimate trends in growth and composition. However, to relate results in a practical way, two comparisons between Suffolk and Texel-sired lambs will be made, one at a constant age of 24 weeks and another at a constant carcass weight of 60 pounds.

Table 1—Performance of Suffolk- and Texel-sired lambs for preweaning and growth traits[a]

Trait	Suffolk	Texel
Number born	2.61	2.63
Birth wt, lb	7.76	7.74
Lamb survival, %	77	86
Preweaning daily gain, lb/day	.49	.48
Weaning wt, lb	33.6	32.9
Weight, lb		
9 weeks	38.6	38.8
15 weeks	68.7	65.7
21 weeks	95.5	89.9
27 weeks	118.9 *	111.1

[a]Probability of declaring the breed difference to be significant when it is actually due to chance (* = 5%).

Results

Ewes mated by Suffolk or Texel rams did not differ for number of lambs born per ewe (Table 1). The breed of sire also showed little difference for birth weight, preweaning growth rate, or weaning weight at 51 days of age. A 9% advantage of Texel-sired lambs for preweaning survival was largely due to fewer lambs found dead at birth. Texel-sired lambs, on an average, grew 11% less rapidly from 9 to 27 weeks of age. The advantage of 8.8 pounds in weight at 27 weeks of age for progeny of Suffolk rams was significant.

Carcass traits of lambs at 24 weeks of age are given in Table 2. Suffolk-sired lambs were 6.7 pounds heavier and produced carcasses that averaged 4 pounds heavier than lambs by Texel sires. The sire breeds were similar for the amount of kidney-pelvic fat, fat depth at the last rib, and loin eye area. Carcasses of Texel-sired lambs had higher leg conformation scores, indicating greater thickness of muscle relative to bone length. However, lambs by Suffolk sires had carcasses of greater length. Because Suffolk-sired lambs had heavier carcasses, each component of the carcass (ash, water, fat, and protein) was heavier than the same component of Texel-sired carcasses. Suffolk-sired lambs had more fat and less protein as a percentage of their carcass weight than progeny by Texel rams.

The data were also summarized in a way that allowed comparisons between sire breeds for lambs that were slaughtered when they all had 60 pound carcasses (Table 2). Suffolk- and Texel-sired lambs each weighed about 113 pounds but progeny of Texel rams required 13 more days to reach this live weight. Suffolk-sired lambs had a little less kidney-pelvic fat and less depth of fat at the last rib. The loin eye area and leg conformation score of Texel-sired lambs were greater than Suffolk-sired lambs. The carcass length of lambs by Suffolk sires was about one inch longer than

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Table 2 – Carcass traits of Suffolk- and Texel-sired lambs at constant age or carcass weight[a]

	24 weeks of age		60 lb carcass wt.	
	Suffolk	Texel	Suffolk	Texel
Slaughter wt, lb	107.2 *	100.5	113.6	113.2
Carcass wt, lb	56.2 *	52.2	60.0	60.0
Slaughter age, days	168	168	175 *	188
Kidney-pelvic fat, lb	1.99	1.89	2.26	2.46
Fat depth last rib, in	.22	.24	.25 **	.29
Leg conformation score	11.8 *	12.5	11.5 *	12.4
Loin eye area, in^2	2.28	2.32	2.36 **	2.57
Carcass length, in	24.3 ***	23.2	24.9 ***	23.9
Ash, lb	2.33 *	2.14	2.48	2.41
Water, lb	28.8	27.5	30.2	30.4
Fat, lb	16.9 **	14.8	18.8	18.5
Protein, lb	8.09	7.75	8.52 *	8.74
Percentage fat, %	29.3	27.8	31.3	31.0
Percentage protein, %	14.6 *	15.0	14.2 *	14.5

[a]Probability of declaring the breed difference to be significant when it is actually due to chance (* = 5%, ** = 1%, *** = .1%).

carcasses of Texel-sired lambs. When compared at a constant carcass weight of 60 pounds, there was little difference between sire breeds in carcass composition. It seems that the composition differences that were present at 24 weeks of age were mostly a consequence of Suffolk progeny growing faster and producing heavier carcasses than Texel-sired lambs.

These results suggest that Texel-sired crossbred lambs may have better survival to weaning, but grow less rapidly after weaning than Suffolk-sired lambs. Although progeny of Texel rams have shorter carcasses, the composition of 60 pound carcasses is similar to carcasses of Suffolk-sired lambs. Generally speaking, breeds that grow quicker produce leaner carcasses at any given carcass weight than breeds that grow slower. The unique feature of the Texel breed seems to be its lean carcass composition relative to its rather average growth rate. We were unable to record feed intake of lambs in this study, so we do not know if feed efficiency from weaning to market weight differs between breeds. Due to the similar composition of 60-pound carcasses, however, we speculate that differences between breeds in feed efficiency, if any, may be of minor importance. As terminal sire breeds, the Suffolk and Texel breeds seem to be comparable. If the greater survival of Texel-sired lambs noticed in this study holds more generally, Texels may have an advantage over Suffolks as a terminal sire breed.

It is likely that the role of the Texel breed in the U.S. sheep industry may eventually extend beyond its use as a terminal sire breed. Because of this, more research is needed to document the performance of purebred and crossbred Texel sheep for lambing difficulty, lamb survival, feed intake, weight of mature sheep, reproductive rate, and longevity. Two major genetic studies were started at MARC to provide this essential information. Other concerns of a practical nature include the known sensitivity of the Texel breed to copper toxicity and the frequent occurrence of inverted eyelids.

Comparison of Finnsheep, Dorset, Romanov, Texel, and Montadale

Larry D. Young[1]

Introduction

The purpose of this paper is to describe a large breed evaluation experiment that has recently been initiated. The experiment will provide a comparison among Finnsheep, Dorset, Romanov, Texel, and Montadale for traits measured throughout the life cycle. The Finnsheep has been included because it is a highly prolific breed that has been used extensively in other breed comparison experiments. The Dorset is used on both the maternal and paternal sides of commercial crossbreeding programs and has also been used widely in research programs. The Romanov and Texel have been chosen for evaluation based upon world literature that indicates they may have desirable characteristics to offer commercial sheep production. These breeds have recently been imported and there are little data comparing them to U.S. breeds for reproduction and growth. The Romanov is a highly prolific breed similar to the Finnsheep. The Texel is of moderate size with good growth rate and carcass characteristics. The Montadale was chosen because it has not been evaluated in a research program and it ranks 10 out of 20 in number of registrations. All breeds ranked above the Montadale in registrations have been, or are being, used in research at some location in the U.S. Thus, it would appear that some research data is needed to help commercial producers determine the most appropriate use of the Montadale.

Objectives of the experiment

1. Evaluate survival, growth, and carcass composition of lambs produced by mating Finnsheep, Romanov, Dorset, Texel, and Montadale rams to Rambouillet and Composite III ewes.

2. Evaluate lamb and wool production and longevity of crossbred ewes produced by mating Finnsheep, Romanov, Dorset, Texel, and Montadale rams to Rambouillet and Composite III ewes.

3. Evaluate spring breeding performance of crossbred ewes produced by mating Finnsheep, Romanov, Dorset, Texel, and Montadale rams to Rambouillet and Composite III ewes.

History of Romanov, Texel, and Montadale

The Romanov originated in the Soviet Union during the 18th century from a short-tailed Nordic breed. The Romanov and Finnsheep were developed in the same general area of the world and many scientists believe that the two breeds have the same origin and trace back to the European mouflon. The Romanov has many characteristics in common with the Finnsheep. Research in Russia, Spain, France, and Hungary indicates that the Romanov is slightly superior to the Finnsheep in adaptability, length of breeding season, puberty, lamb survival, and ewe productivity. Canadian researchers reported that Romanov crossbred ewe lambs were similar to Finnsheep crossbred ewe lambs in ovulation rate and litter size but earlier to reach puberty under western Canadian conditions. Romanov lambs are all black at birth, except most have a white spot on the forehead, and then turn gray as a result of a mixture of black hair and white wool

fibers. The males have a mane of long black hair around the neck and the brisket. These fleece characteristics may limit the use of Romanov in crossbreeding programs.

The Texel is native to The Netherlands having evolved on the Isle of Texel. It is widely recognized for its superior carcass leanness relative to European breeds of sheep. The Texel breed has been evaluated as a terminal sire breed in numerous European studies. With regard to growth and carcass composition, results of these experiments were in general agreement: 1) the Texel-sired lambs grew less rapidly than Suffolk-sired lambs, and 2) Texel-sired lambs excelled in percentage lean. These results provided the basis for the 1985 importation of Texels to MARC. Preliminary results of an experiment comparing postweaning performance and carcass merit of Texel-sired and Suffolk-sired lambs at MARC indicates that Texel-sired lambs grew slower than Suffolk-sired lambs, but there was no difference in carcass composition when compared at the same weights. Evaluation of reproductive ability of the Texel relative to other U.S. breeds is almost non-existent, but such information is necessary to determine the role and contribution of the Texel in commercial and purebred production.

The development of the Montadale was initiated by E. H. Mattingly in 1932. The Montadale Sheep Breeders Association was founded in 1945. The Montadale was developed by crossing Cheviot rams on Columbia ewes. There are virtually no objective comparative data involving the Montadale. Lambing rates are between 175 and 200%, making it comparable to the Texel and Dorset. It produces a white fleece that is 3/8 or 1/4 blood with a 4-inch staple length on a 12-month fleece. There are no objective data available to determine if this breed does or does not have anything unique to offer the commercial sheep industry.

Procedure

Finnsheep, Dorset, Romanov, Texel, and Montadale rams will be mated to Rambouillet (40-50 per ram breed per season) and Composite III (30-40 per ram breed per season) ewes for three years (1990, 1991, 1992) during three separate fall mating periods that will begin on or about August 8, October 15, and December 15 each year. The number of Rambouillet and Composite III ewes exposed to rams will be slightly larger in August than in October and December because of the expected lower conception rate in August. Ewes bred in August will be teased with vasectomized rams beginning about 1 month prior to introduction of fertile rams. The goal is to produce 20 replacement ewe lambs from each sire breed by dam breed combination in each season of each year for evaluation of ewe reproduction.

Six rams of each breed will be used in all three seasons. Six new rams of each breed will be used each year. Finnsheep, Dorset, and Montadale rams will be purchased each year. All Romanov rams will come from the MARC flock since our Romanov population is as broad as the original sample released from Canadian quarantine and thus, no additional sampling appears to be required. With the exception of one small Canadian importation, the Texels imported by MARC provide the genetic foundation for the Texel breed in the U.S.

All lambs (from purebred and crossbred dams) will be weighed at birth and at weaning (average age of 56 ± 4 days) and at 70 ± 4 and 140 ± 4 days of age. Scores will be recorded

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on all lambs for vigor and difficulty of birth. All males will be castrated at about 2 weeks of age.

All sound, healthy, first-cross ewe lambs up to 20 per sire breed by dam breed combination will be retained for breeding. First-cross ewes will be mated to a group of fertile Suffolk rams (20-25 ewes per ram) so as to lamb at one, two, and three years of age. All fall breeding periods will be 35 days long.

Ewes will be held open during the fourth fall breeding season and bred the following spring to evaluate spring breeding performance. During this phase, ewes from all groups upon completion of their third lambing will be randomly assigned within breed group and period of birth to one of two spring mating periods. Each spring breeding period will be 42 days in length, with one beginning on or about February 15 and the other on or about May 15 each year. Ewes will be bred in the spring for two years and will be removed from the project after the second lambing season.

Fleece weights and fleece quality will be measured on ewes shorn just before lambing at two years of age.

First-cross wether lambs (approximately 200 per year) from the second lambing season will be slaughtered in the abattoir each year. Traits recorded at slaughter will be live weight, carcass weight, kidney fat weight, electrical impedance, fat thickness, carcass length, loin eye area, leg score, yield grade, and quality scores. These measurements will be used to estimate weight of lean in the carcass.

Comparison of Booroola Merino and Finnsheep:
Effects on Productivity of Mates and Performance of Crossbred Lambs

Larry D. Young and Gordon E. Dickerson[1]

Introduction

The highly prolific Finnsheep was imported into the U.S. in the late 1960's as a possible source of genes for increasing lambing rates of commercial sheep flocks. Since then, research has shown that for every 1% increase in Finnsheep breeding in the ewes, there was approximately a 1% increase in number of lambs born per ewe lambing. The increased prolificacy of the Finnsheep is presumed to be because of a large number of genes with small effects.

The Booroola Merino is an alternative source of germ plasm to increase prolificacy. It is the only known highly prolific breed with an unpigmented, Merino-quality fleece. Its increased reproduction is controlled by a single major gene, or group of very closely linked genes acting as a single gene, that causes a large increase in ovulation rate and consequently litter size. This gene is called the Fecundity (F) gene and has no documented effect on any other performance characteristics.

The different genetic mechanisms controlling prolificacy in the Finnsheep and Booroola Merino offer different opportunities for development of breeding and production programs to increase the level of reproduction in commercial sheep flocks. Using these breeds correctly requires an understanding of their relative level of performance for all traits that are economically important to sheep producers.

The purpose of this paper is to compare performance of Booroola Merino and Finnsheep rams mated to Finnsheep and crossbred ewes and to compare performance of their progeny.

Procedure

Booroola Merino and Finnsheep rams were mated in single-sire pens to Finnsheep and crossbred ewes (½ Columbia, ¼ Suffolk, and ¼ Hampshire) for 35 days beginning December 14, 12, 4, and 3, of 1983, 1984, 1985, and 1986, respectively. Ewes of each breed were assigned to each ram in order that one-half of the ewes of each breed were assigned to each breed of ram. Similar ram to ewe ratios were used for each breed of ram. A total of 32 Finnsheep and 18 Booroola Merino rams were used.

Except during breeding, the ewes were managed as a single group. During the gestation period, the ewes were on pasture, but supplemental feed was provided as needed to meet their nutritional requirements. Four to six weeks before lambing, the ewes were shorn, drenched, vaccinated for types C and D enterotoxemia, and given an injection of Vitamins A, D, and E. Lambs were born and raised in a facility with an elevated, woven-wire floor. When a ewe did not have enough teats or milk to rear all of her lambs, the excess lambs were moved to an artificial rearing facility. Lambs that were least successful in obtaining milk from the ewe were moved to the nursery. Lambs entering the nursery were fed 60 to 120 ml of bovine colostrum and trained to use artificial nipples. Lambs in the nursery were self-fed on a commercially prepared ewe milk replacer and creep feed. In order to restrict the cost of milk replacer, nursery-reared lambs were weaned to dry diets at approximately 35 days of age. Ewe-

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reared lambs had access to creep feed and were weaned at approximately 63 days of age. All lambs were weighed at birth, weaning and at an average of 147 days of age.

Finnsheep and Booroola Merino x Finnsheep rams retained for breeding (20% of Finnsheep and 17% of Booroola Merino x Finnsheep) were randomly chosen from the sound, healthy ram lambs within each ram progeny group. Rams not needed as replacements were slaughtered in groups of approximately 60 after reaching a minimum of 100 pounds live weight, and carcass data were recorded. All healthy ewe lambs were moved to outside dirt lots and monitored for age at first estrus by exposure to vasectomized rams beginning at 21 weeks of age. At approximately 28 weeks of age, all sound, healthy ewe lambs were exposed to fertile rams for 35 days.

Breeding marks were recorded three times each week before breeding started and daily during breeding. Ovulation rate was evaluated by laparoscopic examination 3 to 10 days after the first mating of each ewe lamb to a fertile ram. Embryo survival (number of lambs born per egg ovulated) was measured in ewes that were bred to lamb at one year of age.

Results

Because the objectives of this experiment were to compare Finnsheep and Booroola Merino for direct additive genetic effects and to determine if these direct effects were different based on the performance level of the breed of ewe, this discussion will focus on breed of ram effects and the interaction of breed of ram with breed of ewe. Breed of ewe effects will be presented, but will not be discussed except as they relate to important interactions with breed of ram.

Productivity traits of Finnsheep and crossbred ewes mated to Booroola Merino and Finnsheep rams are presented in Tables 1 and 2. There was no difference between Booroola Merino and Finnsheep rams for fertility, total number born, number born alive, litter birth weight, number of lambs weaned by the ewe, or number of lambs weaned in the nursery. Litter weight weaned by the ewe per ewe lambing and per ewe joined was higher for Finnsheep rams than Booroola Merino rams. This was due to an advantage of lambs from Finnsheep rams in preweaning growth and consequently weaning weight (Table 3) and not to an advantage in litter size (Table 1) or lamb survival (Table 4). The advantage of Finnsheep rams relative to Booroola Merino rams for litter weight weaned by the ewe per ewe lambing was 2.5 times larger for crossbred ewes than for Finnsheep ewes; similarly the advantage per ewe joined was 4.3 times larger for crossbred ewes than for Finnsheep ewes. These results reflect similar interactions in weaning weight (Table 1) and, to some extent, lamb survival (Table 4). Litter weight weaned in the nursery per ewe lambing or per ewe joined did not differ between Finnsheep and Booroola Merino rams.

Birth weight, weaning weight of ewe-reared and nursery-reared lambs, and 147-day weight of ewe-reared lambs are presented in Table 3. Differences between ram breeds were very small for birth weight. However, weaning weight was greater for Finnsheep-sired lambs than for Booroola Merino-sired lambs whether they were raised by the ewe or in the nursery. The difference in weight at weaning (6.0 lb) of ewe reared lambs was maintained until 147 days of age (6.9 lb),

Table 1—Means for breed of ram, breed of ewe and their interaction for fertility and ewe productivity traits at birth[a]

	No. ewes exposed	Fertility, %	No. ewes lambing	Total no. born	No. born alive	Litter birth wt, lb
Breed of ram						
FS[b]	616	77.0	468	2.26	2.10	18.78
BM[b]	710	80.7	561	2.20	2.06	18.47
Breed of ewe						
FS	659	84.8	536	2.85	2.62	18.23
CO[b]	667	72.9	493	1.60	1.54	19.00
Breed of ram by breed of ewe						
FS x FS	297	81.6	228	2.88	2.64	18.36
BM x FS	362	87.9	308	2.82	2.60	18.10
FS x CO	319	72.4	240	1.63	1.56	19.18
BM x CO	348	73.4	253	1.58	1.53	18.85

[a]Adjusted to a ewe age of 2.8 years at lambing.
[b]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk.

Table 2—Means for breed of ram, breed of ewe and their interaction for ewe productivity measured at weaning[a][b]

	Number weaned by		Litter wt weaned by		Litter wt, lbs weaned per ewe joined	
	Ewe	Nursery	Ewe	Nursery	Ewe	Nursery
Breed of ram						
FS[c]	1.55	.26	72.07	4.17	55.23	3.28
BM[c]	1.50	.27	61.09	3.92	48.92	3.24
Breed of ewe						
FS	1.61	.51	59.19	7.72	50.24	6.28
CO[c]	1.43	.02	73.97	.37	53.90	.24
Breed of ram by breed of ewe						
FS x FS	1.63	.49	62.35	7.61	51.41	6.08
BM x FS	1.60	.53	56.04	7.80	49.07	6.50
FS x CO	1.47	.04	81.77	.71	59.04	.48
BM x CO	1.39	.01	66.14	.04	48.79	.00

[a]Ewe-reared lambs were weaned and weighed at an average of 63 d of age. Nursery-reared lambs were weaned and weighed at an average of 35 d of age.
[b]Adjusted to a ewe age of 2.8 years at lambing.
[c]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk.

Table 3—Means for breed of ram, breed of ewe and their interaction for lamb weights at various ages[a][b]

	Birth wt, lb		Weaning wt, lb				147-d wt, lb	
			Ewe-reared		Nursery-reared			
	No. obs.	Mean	No. obs.	Mean	No. obs.	Mean	No. obs.	Mean
Breed of ram								
FS[c]	975	9.06	701	47.2	88	17.2	658	88.0
BM[c]	1155	9.15	805	41.2	111	15.2	772	81.1
Breed of ewe								
FS	1318	6.39	806	37.3	171	15.2	770	75.8
CO[c]	812	11.82	700	51.1	28	17.2	660	93.3
Breed of ram by breed of ewe								
FS x FS	575	6.39	346	39.2	72	16.3	327	78.0
BM x FS	743	6.39	460	35.3	99	14.3	443	73.6
FS x CO	400	11.75	355	55.1	16	17.9	331	97.9
BM x CO	412	11.90	345	47.4	12	16.3	329	88.6

[a]Adjusted to a ewe age of 2.8 years at lambing
[b]Ewe-reared lambs were weaned and weighed at an average of 63 d of age. Nursery-reared lambs were weaned and weighed at an average of 35 d of age.
[c]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk

but did not substantially increase beyond the difference at weaning. For ewe-reared lambs, the difference in weaning weight and 147-day weight of Finnsheep-sired and Booroola Merino-sired lambs was about twice as large for lambs from crossbred ewes compared to lambs from Finnsheep ewes; the magnitude of these differences did not change substantially from weaning to 147 days of age.

Survival at birth and from birth to weaning are summarized in Table 4. There was no difference between lambs from Finnsheep and Booroola Merino rams for survival at birth or for survival from birth to weaning when raised by the ewe or in the nursery. Relative to Booroola Merino-sired lambs, Finnsheep-sired lambs had a 4.3% higher survival rate when produced by crossbred ewes, but a 3.7% lower survival rate when produced by Finnsheep ewes.

Ram lamb carcass weight and carcass tenth-rib fat thickness are presented in Table 5. Carcasses from Finnsheep-sired lambs were heavier (1.7 lb) and had less fat

thickness (.05 in) than those from Booroola Merino-sired lambs.

Reproductive traits measured on ewe lambs are summarized in Table 6. A higher percentage of Finnsheep-sired ewe lambs reached puberty at a younger age than did Booroola Merino-sired ewe lambs regardless of the breed of ewe. However, the advantage for Finnsheep-sired ewe lambs was substantially larger when produced by crossbred ewes than by Finnsheep ewes. Date on estrus detection was kept only during the first breeding season, thus, the age at puberty was not recorded in all the ewes and the observed average ages at puberty are biased. Because of this, scientists adjusted the observed averages to allow unbiased comparisons to be made among groups which had different percentages of ewe lambs reaching puberty. These adjusted averages are presented in Table 6. This adjustment further magnifies the delayed puberty of Booroola Merino x crossbred ewes relative to the other genotypes.

Table 4—Means for breed of ram, breed of ewe and their interaction for lamb survival at birth and until weaning[a]

| | | | Survival to weaning | | | |
| | Survival at birth | | Ewe-reared | | Nursery-reared | |
	No. obs.	Mean	No. obs.	Mean	No. obs.	Mean
Breed of ram						
FS[b]	975	94.1	781	90.3	139	76.8
BM[b]	1155	95.0	907	89.9	194	64.8
Breed of ewe						
FS	1318	92.0	936	86.5	291	67.9
CO[b]	812	97.1	752	93.7	42	73.7
Breed of ram by breed of ewe						
FS x FS	575	91.7	411	84.7	119	69.0
BM x FS	743	92.3	525	88.4	172	66.8
FS x CO	400	96.5	370	95.8	20	84.5
BM x CO	412	97.8	382	91.5	22	62.8

[a]Adjusted to a ewe age of 2.8 years at lambing.
[b]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk.

Table 5—Means for breed of ram, breed of ewe and their interaction for carcass weight and fat thickness measured on ram lambs[a][b]

	No. obs.	Carcass weight, lb[b]	Fat, thickness in[b]
Breed of ram			
FS[c]	266	57.3	.23
BM[c]	349	55.6	.28
Breed of ewe			
FS	284	56.0	.23
CO[c]	331	56.8	.28
Breed of ram by breed of ewe			
FS x FS	102	56.7	.20
BM x FS	182	55.4	.26
FS x CO	164	57.8	.26
BM x CO	167	55.8	.30

[a]Adjusted to ewe age of 2.8 years at lambing.
[b]Adjusted to a live weight of 106 lb.
[c]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk.

The expectations for performance due to the genetics of Finnsheep x crossbred ewes, Booroola Merino x crossbred ewes and Booroola Merino x Finnsheep lambs are based on the effects of individual heterosis (hybrid vigor) while the performance expectation for purebred Finnsheep is not. Thus, the comparison between Finnsheep x crossbred ewes and Booroola Merino x crossbred ewes contains differences that are due to direct additive genetic effects from each of these breeds. The comparison of purebred Finnsheep to Booroola Merino x Finnsheep contains differences due to direct additive genetic effects of the breeds and to individual heterosis (or hybrid vigor). Because of this difference, the best estimate of direct additive genetic differences between the two ram breeds resulted from comparing them when mated to crossbred ewes. This comparison shows that Booroola Merino-sired lambs were slower growing, especially pre-weaning, and had a lower survival rate from birth to weaning when raised by the ewe. At a constant live weight, Booroola Merino-sired lambs produced lighter carcasses than Finnsheep-sired lambs, which was probably a reflection of differences in wool production and pelt weight. Relative to Finnsheep-sired progeny, Booroola Merino-sired progeny had

a substantial disadvantage in percentage of ewe lambs reaching puberty, age at puberty, and embryo survival (or uterine capacity), but had a greater ovulation rate and nearly equal litter size.

Final determination of the relative usefulness of these breeds to produce replacement ewes will depend upon results of work in progress to evaluate lamb and wool production of ewes at later ages.

Table 6—Means for breed of ram, breed of ewe and their interaction for puberty, ovulation rate, litter size and embryo survival[a]

	Percentage reaching puberty[b]		Puberty age, d			Corpora lutea		Lambs born		Embryo survival
	No. obs.	Mean	No. obs.	Mean	Adj. Mean[c]	No. obs.	Mean	No. obs.	Mean	Mean
Breed of ram										
FS[d]	358	97.1	345	182.1	183.2	284	1.87	219	1.76	95.1
BM[d]	395	78.6	318	189.4	196.5	253	2.21	194	1.82	83.9
Breed of ewe										
FS	423	96.2	400	183.7	185.1	319	2.30	247	2.07	91.7
CO[d]	330	79.5	263	187.8	194.6	218	1.79	166	1.51	87.4
Breed of ram by breed of ewe										
FS x FS	189	97.0	182	181.9	182.9	136	2.06	104	1.96	95.0
BM x FS	234	95.4	218	185.5	187.1	183	2.53	143	2.18	88.3
FS x CO	169	97.2	163	182.4	183.4	148	1.69	115	1.56	95.3
BM x CO	161	61.8	100	193.3	206.8	70	1.89	51	1.47	79.5

[a]Adjusted to ewe age of 2.8 years at lambing.
[b]Percentage reaching puberty is the percentage of ewe lambs reaching puberty by the end of their first breeding season.
[c]Least squares means after adjusting for differences in percentage of ewe lambs reaching puberty. All groups are adjusted to 100% reaching puberty.
[d]FS = Finnsheep, BM = Booroola Merino, and CO = crossbred, ½ Columbia, ¼ Hampshire, ¼ Suffolk.

Comparison of Romanov and Finnsheep Mated to Composite III Ewe Lambs

Larry D. Young, Brad A. Freking and Mike H. Wallace[1]

Introduction

The Romanov and the Finnsheep are both highly prolific breeds. Researchers at MARC have been studying these breeds, comparing them to each other in order to understand performance similarities and differences that may be useful to sheep producers.

Procedure

From December 20, 1989, to January 24, 1990, 5 Romanov and 5 Finnsheep rams were group-mated to 102 and 97 MARC Composite III ewes (½ Columbia ¼ Suffolk ¼ Hampshire), respectively. The lambs were born and reared in a raised deck confinement facility. Male lambs were castrated when they were about 14 days old. Five Finn-sired lambs and one Romanov-sired lamb were moved to the nursery because ewes were unable to raise twins or did not have enough milk. During lactation, ewes were fed a corn silage-alfalfa hay-corn-soybean meal ration which was 52% dry matter, 71% totally digestible nutrients, and 16% crude protein. Lambs were provided free choice creep feed of the same feed components which was 89% dry matter, 81% totally digestible nutrients, and 18% crude protein. After weaning, lambs were fed the same ration (as much as they wished to eat) until they reached 70 pounds.

At that weight, the soybean meal was decreased and corn increased to reduce the crude protein to 14.5%. When the lambs reached 90 pounds, the soybean meal was decreased again to bring the ration down to 12% crude protein. Lambs were weaned at 9 weeks. Weights were recorded at birth, weaning, and 22 weeks of age. At 22 weeks of age, the lambs were inspected for the presence of hair or black fibers on the neck, side, or britch. Each location on the lamb's body that had black fibers or hair was given a score of "1" for that location. If they had no hair or black fibers, each location was scored a "0". When the lambs were slaughtered, wether lamb pelts were graded by a commercial pelt grader at Iowa Lamb Corporation, Hawarden, Iowa.

These data were statistically analyzed to determine differences between the sire breeds for average interval to lambing, percentage of ewes lambing, lambs born per ewe lambing or per ewe exposed and incidence of hair and black fibers in the wool.

[1]Young is a research geneticist, Freking is a computer programmer, Genetics and Breeding Research Unit; and Wallace is Sheep Operations Manager.

Table 1—Least squares means for reproduction traits measured on Composite III ewe lambs mated to Romanov and Finnsheep rams

Item	Breed of Ram	
	Romanov	Finnsheep
No. ewes exposed	102	95
No. ewes lambing	97	83
Avg. interval to lambing, days[a]	158.3	157.7
Percentage lambing	95.1	87.4
Lambs born/ewe lambing	1.08	1.16
Lambs born/ewe exposed	1.03	1.01

[a]This is the interval from the date rams were placed with the ewes until lambing date for ewes lambing.

Table 2—Least squares means for growth and survival traits of lambs produced from matings of Romanov and Finnsheep rams to Composite III ewe lambs

	Breed of Sire	
	Romanov	Finnsheep
No. of lambs	105	96
Birth wt, lb	11.16	11.37
Weaning wt, lb[a]	50.5	50.1
22-wk wt, lb	106.8	107.1
Daily gain, B-W, lb/d[b]	.64	.62
Daily gain, W-22 wk,lb/d[c]	.60	.61
Survival to weaning[d]	93.4	93.0
Survival to 22 wk[e]	91.6	91.9

[a]Adjusted to 9 weeks of age for dam-reared lambs.
[b]Average daily gain from birth to weaning using actual ages and weights of dam-reared lambs.
[c]Average daily gain from weaning to 22 wk of age using actual ages and weights of dam-reared lambs.
[d]Survival to weaning of all lambs born alive for dam-reared lambs. (Only 2 lambs were born dead; they were sired by Romanov rams.)
[e]Survival to 22 wks of age of all lambs born alive for dam-reared lambs.

Results

Table 1 shows how the breed of sire affected 1) the interval from beginning of exposure to the ram to the average lambing date, 2) percentage of ewes lambing, 3) lambs born per ewe lambing, and 4) lambs born per ewe exposed. The only significant difference between the two ram breeds was for percentage of ewes lambing.

Table 2 shows how the breed of sire affected 1) birth weight, 2) weaning weight, 3) 22 week weight, 4) daily gain from birth to weaning, 5) daily gain from weaning to 22 weeks old, 6) survival from birth to weaning, and 7) survival from birth to 22 weeks old. Differences between ram breeds for these traits were very small and not statistically significant.

Table 3 shows how the breed of sire affected the percentage of lambs with hair or black wool fibers on the neck, side, britch, or at least one of these locations. The Romanov-sired lambs showed a higher frequency of these traits on all body parts. Of these Romanov-sired lambs, a higher percentage had hair fibers than black fibers.

Table 4 shows a tabulation of the pelt classes by sire breed. Breed differences were not important except for the black pelts from some of the Romanov-sired lambs.

Table 3—Least squares means for fleece characteristics of dam-reared lambs produced from matings of Romanov and Finnsheep rams to Composite III ewe lambs

Item	Breed of Sire	
	Romanov	Finnsheep
No. sampled	93	83
% with hair on neck	16.1	2.4
% with hair on side	20.4	1.2
% with hair on britch	62.4	.6
% with hair	67.7	9.6
% with black on neck	11.8	.0
% with black on side	11.8	.0
% with black on britch	24.7	.0
% with black	28.0	.0

Table 4 – Commercial pelt grade classification for wether lambs produced by mating Romanov and Finnsheep rams to Composite III ewe lambs

Item	Breed of Sire	
	Romanov	Finnsheep
No. observations	44	51
Full wool	8 (18.2%)	1 (2.0%)
Spring	31 (70.5%)	49 (96.0%)
Spring cut	2 (4.5%)	1 (2.0%)
Spring black	3 (6.8%)	0 (0%)

The only significant differences between the Finnsheep-sired lambs and the Romanov-sired lambs in this study were for the percentage of ewes lambing and in fleece characteristics.

However, the differences in these traits can be significant to producers. Differences in percentage of ewes lambing was 7.7% in favor of the Romanov. Because ewes were group mated, it is most likely that all ewes in estrus were bred. However, neither Romanov nor Finnsheep are likely to be used as sires of market lambs. It is more likely that these breeds would be used to produce crossbred replacement ewes. Because of this, the greater percentage of Romanov ewes lambing is not as important as if Romanov were used as terminal sires. The differences in fleece, however, could be very important, since the crossbred ewe will be shorn every year she is in the flock. The Romanov crossbred ewes will produce fleeces with more hair and black fibers than the Finnsheep crossbred ewes. These fleece differences will probably be passed down in some degree to the Romanov crossbred ewes' offspring, depending on the breed of ram they are mated to. However, there may be a difference in the percentage of hair and black wool fibers in Romanov-sired ewes depending on the breed of their dam. The composite ewe used in this study is ½ Columbia, ¼ Hampshire and ¼ Suffolk. Results may differ if the ewe was a pure white-faced breed.

The Finnsheep- and Romanov-sired ewe lambs produced in this study are being mated to Suffolk rams at 7 months of age so they will lamb at 12 months of age. The fleeces of these ewes (11 months first clip) will be weighed and commercial grades determined. Lambing data and offspring performance also will be determined from the first lamb crop.

Productivity of Ewes Assigned to Twice a Year Lambing Compared to Productivity of Annual Lambing Ewes

Thomas G. Jenkins and J. Joe Ford[1]

Introduction

The number of lambs available for marketing can be affected by the management decisions concerning the ewe flock. Identification of breeds or breed crosses that reach sexual maturity at early ages, have multiple offspring per parturition, and greatest offspring survival will enhance the productivity of a flock. This productivity could be further increased by using management strategies such as accelerated lambing programs and altering the breeding season by using exogenous hormones. Within maternal breeds or breed crosses of sheep, there isn't much information available evaluating the effect of using alternative management strategies on annual ewe productivity.

The objective of this study was to evaluate measures of annual ewe productivity for a prolific breed cross, and to determine if annual ewe productivity is affected by using different management strategies. Specific objectives included: 1) determining if the annual productivity of ewes of a prolific breed cross is increased for ewes assigned to 6-month lambing programs (accelerated) relative to the productivity of prolific breed crosses lambing once a year (annual), 2) to decide if an optimal breeding season within accelerated lambing system could be defined and 3) evaluate the effectiveness of exogenous hormone (progestin) therapy for increasing annual ewe productivity.

Procedures

Approximately 320 cross bred ewes (.5 Finnsheep – .25 Dorset – .25 Rambouillet) born in 1979, 1980, and 1981 were assigned to the study. Grouped according to their year of birth, the ewes were randomly assigned to one of four experimental flocks. Experimental flocks included three flocks managed to lamb at 6-month intervals and a flock that lambed once a year that served as a standard for comparison. For the breed cross used in this study, the yearly estrous activity period is approximately 211 days. Following an anestrous period occurring yearly in June and July, approximately 80% of the ewes would be expected to express estrous activity by early to mid September. Through April and May over 60% of the ewes would be expected to be cyclic. Using this information, 30-day breeding seasons were identified for the experimental flocks assigned to the accelerated lambing programs. The breeding seasons for the flocks were as follows:

Flock	Fall	Spring
1	August 15 through September 15	February 15 through March 15
2	September 15 through October 15	March 15 through April 15
3	October 15 through November 15	April 15 through May 15

The breeding season for the annual lambing flock was:

4 October 15 through November 15

Within each of the four flocks, one-half of the ewes were assigned to treatment with progestin impregnated pessaries to reduce the postpartum anestrous period. Ewes assigned to the accelerated flocks received pessaries at a minimum of 10 days post partum. The pessaries were removed 12 days after insertion. All ewes of the annual flock subjected to progestin therapy treatment received vaginal pessaries 12 days prior to the initiation of the fall breeding season. Ewes within all flocks were exposed to a minimum of two fertile rams within each breeding season.

The same animal husbandry practices were used for all experimental flocks. Following weaning at an average of 58 days, ewes were transferred to pastures that were primarily smooth Brome (Bromus) grass. When the ewes were on pasture, required supplementary energy (grass hay) was provided as needed. Flocks were returned to confinement for lambing as follows: Flock 1, June 1 and December 1; Flock 2, July 1 and January 1; Flock 3, August 1 and February 1 for fall and spring lambing seasons, respectively. Return of the annual lambing flock coincided with the return of Flock 3 for spring lambing. When Flocks 3 and 4 were in confinement, the flocks were managed as a single band.

In confinement, the flocks were housed in separate pens within a poleshed with an outside run attached to each pen. Each flock was assigned 2 pens inside the poleshed. One of these pens was designated a drop pen and the second a mixing/rearing pen. Outside runs were available with both pens. At birth, new born lamb(s) and ewe were housed in small pens for 24-36 hours to encourage acceptance of the offspring by the ewe. Ewes giving birth to two or more lambs were challenged to rear the litter. To make this easier, the mixing pen of each flock was subdivided to allow separation of lactating ewes into two groups; a group for those ewes rearing three or more lambs and a second group for ewes rearing singles and twins. Ewes in the first group received additional feed. If it was determined the ewe could not rear all her lambs, the ewe didn't accept her lambs, or the ewe died, lambs were cross fostered (within progestin treatment) or transferred to a nursery facility. At birth, lamb identification number, birth date, type of birth, birth weight, sex and dam ID were recorded for each lamb. Tails of the lambs were docked and male lambs castrated at approximately 1-2 weeks of age. Within each flock, lambs nursing ewes were weaned at approximately 8 weeks of age. Nursery lambs were considered weaned at approximately 5 weeks of age. Weights at weaning and the type of rearing were recorded for each lamb at time of weaning.

While in confinement, pregnant ewes were fed a ground alfalfa hay, corn silage based diet that contained approximately 67% total digestible nutrients (TDN) and 12% crude protein (CP). The TDN and CP content of the diet for lactating ewes was increased to 72% and 14%, respectively. Ewes raising more than twins had this diet top-dressed with pelleted alfalfa (72% TDN, 14% CP). A ground alfalfa, corn and soybean meal creep feed containing 81% TDN and 18% CP was provided ad libitum (as much as they wished to eat) for the lambs.

The number of ewes exposed, lambing, and number of lambs born and weaned, were recorded by breeding season within the flock 12 month production period. Weight of lambs weaned was also recorded. These data were then related to the number of total ewes maintained during the production year. Weaning weights were adjusted for age at weaning, birth type and type of rearing. The study was conducted for three years. Then this information was related to the number of ewes maintained in the flock each year for an average. The numbers of lambs born, weaned, and pounds of lambs weaned per ewe maintained were compared between the

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[1]Jenkins is a research animal scientist, Production Systems Research Unit; Ford is a animal research physiologist, Reproduction Research Unit.

Table 1 – Number of ewes exposed and number of ewes lambing by breeding season periods for each of three cycles of production

| Breeding Season | Year of Production | | | | | |
| | 1982 Ewes | | 1983 Ewes | | 1984 Ewes | |
	Exposed	Lambed	Exposed	Lambed	Exposed	Lambed
Annual						
Flock 4						
October-November	73	73	69	60	48	41
Accelerated						
Flock 1						
February-March	77	30	82	28	62	35
August-September	80	49	76	39	52	23
Flock 2						
March-April	72	7	74	5	61	6
September-October	75	71	68	61	58	55
Flock 3						
April-May	80	1	84	2	64	5
October-November	84	77	82	66	52	56

annual and accelerated flocks. Within the accelerated flocks, the same measures of productivity were compared for the different breeding seasons.

Results

Ewe exposures and lambings by year are presented in Table 1. Very few ewes lambed in both spring and fall. The ewes in Flock 1 seemed to establish annual production cycles as either spring or fall breeders. Ewes in Flock 1 showed a 10% twice a year lambing rate, relative to the total numbers of matings of these ewes. In flocks 2 and 3, very few ewes lambed in the fall, and the ewes that did fall lamb were open from the previous spring lambing.

Total numbers of lambs born and weaned for the three cycles of production are reported in Table 2. Average age of weaning for the lambs reared by the ewes was 58 days and 32 days for lambs reared in the nursery. Survivability through weaning was similar among the four flocks; being 82%, 81%, 79% and 82% for the Flocks 1, 2 and 3 accelerated) and Flock 4 (annual), respectively.

Rate of conception, lambing, weaning or weight of lamb weaned per ewe maintained per year was approximately the same for the annual lambing flock and the average of the three accelerated flocks (Table 3). The annual productivity of the accelerated system ewes did show a tendency to exceed the annual lambing ewes. For example, the increased frequency of the accelerated systems ewes' exposure to rams resulted in a conception rate greater than 100%, as ewes that didn't settle the previous breeding season, did conceive when exposed 6 months later. This gave the accelerated system ewes approximately a 3% advantage in the number of lambs born per ewe exposed per year. In this particular study significant differences were not observed in productivity among the three different breeding seasons of the accelerated lambing systems. Over the three years of the study however, the trend was for conception rate per ewe maintained per year to be approximately 5-7 percentage units higher in Flock 2 compared to the other accelerated flocks (Table 3). The higher conception rate for Flock 2 did increase productivity as measured by lambing rate and lambs weaned per ewe exposed.

It certainly seems that accelerated lambing programs with prolific ewes should provide an excellent opportunity to

Table 2 – Number of lambs born and number of lambs weaned for three cycles of production from three lambing systems

| Breeding Season | Year of Production | | | | | |
| | 1982 Ewes | | 1983 Ewes | | 1984 Ewes | |
	Born	Weaned	Born	Weaned	Born	Weaned
Annual						
Flock 4						
October-November	162	135	142	116	94	76
Accelerated						
Flock 1						
February-March	53	42	55	46	81	65
August-September	110	96	86	71	49	34
Flock 2						
March-April	11	10	8	8	12	10
September-October	161	130	156	140	127	88
Flock 3						
April-May	1	1	3	2	8	7
October-November	177	148	163	128	110	79

increase production. An assumed average gestation interval of 145 days for sheep should indicate that a 6 month accelerated lambing system would work. For the mating program to be effective, the postpartum anestrous period should not be longer than approximately 28 days. Conception rate at the first estrus would have to be high, to allow a worthwhile proportion of the ewes to conceive again within approximately 35 days after lambing.

However, the present study indicated that this accelerated lambing program showed very little or no significant improvement in ewe productivity over the annual system. It is important to look carefully at any factors that might have influenced this data. Factors known to affect the successful mating and conception of ewes include nutrition, breed, dystocia (lambing difficulty), breeding season, multiple births, lactation and previous history of bearing live offspring with these effects causing delays in return to estrus, delays in ovulation or failure to ovulate at estrus, failure to conceive or increased embryonic mortality.

In the present study, a single breed cross of ewe was used for both accelerated and annual lambing systems and could not be considered as a source of variation. Nutrition would not be considered as a limiting factor as all ewes were receiving balanced diets with plenty of feed available. Ewes nursing more than twins received as much food as they wished; thus, nutrition was not considered limiting. Although not scientifically evaluated, the lambing records recorded that the frequency of dystocia in these flocks was extremely low. This reduced the probability that dystocia was restricting an increase in ewe productivity.

For the accelerated flocks, the mating seasons were established based on previous research characterizing the estrous activity for this breed cross. The current study was initiated with the 1982 spring breedings. To standardize the flocks, assigned mating seasons were implemented in fall 1981 breeding period and the ewes were exposed to fertile rams. Conception rates for Flock 1 (approximately 45%-55%, unreported data), were in the range expected based upon estimates of estrous activity reported expected for this period. Throughout the study, there were conceptions in Flock 3 from the late spring mating season. Because there were lambings from these two breeding seasons, this indicated that a fertile estrous cycle was occurring during all mating seasons. Therefore, breeding season was not considered as the main limiting factor. Three factors remain to be considered from those listed earlier that could affect the productivity of ewes managed to lamb twice a year; multiple births, lactation and previous parity (history of bearing live offspring).

Regarding previous parity, about 10% of the ewes in Flock 1 had successful reproductive events at every opportunity. Data that could provide documentation on estrous or ovulatory activity were not collected. Therefore, one can only speculate that if a ewe failed to lamb in a subsequent lambing period it was because of a lack of expression of estrous activity or low fertility. Applying this concept to this research suggests that normal cyclicity would be expected by the beginning of breeding. Because successive lambings were observed for about 10% of the ewe population, this study seems to indicate that previous parity would not inhibit estrous activity by 35 days postpartum (after lambing) in ewes. Thus, if an effect of previous parity is a factor on successful reproduction in a 6-month program, this effect must be mediated by other means, such as reduced conception rates or increased incidence of early embryo mortality.

There has been no direct evidence suggesting a negative effect of litter size on the successful rebreeding of ewes in a 6-month lambing according to previous research efforts. Some information suggests that increased prolificacy of a breed or breed cross actually enhanced the frequency of successful rebreedings. The effect of litter size on the successful rebreeding of ewes in an accelerated 6-month lambing program is minimal.

A return to cyclicity following parturition (lambing) may be inhibited by the ewes' lactation. This is logical from an evolutionary standpoint, as inhibiting cyclicity would insure longer care by the ewe for current offspring, increasing chances for survival of the offspring. Sensitivity to both lactation and suckling stimuli may affect the length of the postpartum anestrous period. However, evidence available today concerning the lactational effect is not conclusive.

We need an increased understanding of what factors contribute to the limitation of successive rebreeding of ewes maintained in an accelerated 6-month lambing program. The restriction that rebreeding is required within approximately 40 days post lambing implies a shortened postpartum interval, full recovery of the reproductive tract from lambing (Involution), conception and acceptable embryo survival. Each of these components appear to be influenced by one or more factors such as previous parity, lactation, prolificacy or interactions among these factors. Without increased understanding of how the influence of these factors can be modified, the 6-month accelerated lambing system cannot be generally recommended.

Table 3—Least squares means for measures of annual productivity for ewes under accelerated and annual lambing systems

| | Relative to Ewes Maintained per Production Year | | | | |
| | | | Breeding Season | | |
Trait	Annual	Accelerated	Aug.-Sept./ Feb.-Mar.	Sept.-Oct./ Mar.-April	Oct.-Nov./ April-May
Conceived (*100)	91	98	96	101	94
Lambing Rate (*100)	208	214	204	232	206
Weaned (*100)	170	171	166	188	162
Weight Weaned (lb)	66	64.2	62.5	67.8	62.7

Effect of Production System on Annual Market Lamb Output By ¼ and ½ Finnsheep Ewes

Russell A. Nugent III and Thomas G. Jenkins[1]

Introduction

Management decisions regarding breeding system, labor and genetics affect the output of market lamb production systems. Accelerated lambing and other intensive management practices (e.g., artificial rearing and hormonal or light treatment) can increase productivity, but larger overhead costs associated with the extra labor and specialized facilities required to operate intensive management systems may not be offset by gains in ewe productivity (pounds of lamb weaned per ewe per year). Reproductive efficiency of the ewe and growth potential and survivability of the lamb are components of ewe productivity. Therefore, increases in ewe breeding opportunities per year, fertility, litter size and lamb preweaning growth and survival rate through use of prolific, non-seasonal maternal breed crosses would also increase productivity. The relative productivity of certain breed crosses may differ with the various environments created by different management strategies, however. Crossbred Finnsheep (Finn) ewes are desirable for their high prolificacy, but increased litter size may not be advantageous in all production environments. The present study was designed to study the effects of alternate management systems which varied in labor intensity on the relative performance of ¼ and ½ Finn ewes.

Procedure

This study was conducted from September 1978 through (breeding in) May 1982. Ewes born in 1977 or 1978 that were either ¼ or ½ Finn (remainder was primarily Rambouillet) breeding were bred to Suffolk or Columbia rams in one of three systems: high labor and capital input accelerated lambing, high input annual, or low input annual. Systems are outlined in Table 1. Ewes were maintained on similar pastures and received energy, protein and mineral supplementation as deemed necessary. All ewes were provided corn silage from mid-November through mid-April. Management practices other than what was mentioned above were the same for all three systems. Ewes were generally culled only for illness or unsoundness which interfered with reproduction.

Accelerated lambing system ewes were exposed to rams for 34 days each September, January and May while the high labor, annual lambing (November) and low labor, annual lambing (December) system ewes were exposed only 34 days annually. Ewes exposed during May were fitted with progesterone treated vaginal pessaries 14 days prior to the breeding season. Pessaries were removed and an injection of 500 international units of pregnant mare serum was given just prior to ram introduction. Facilities for light treatment of rams used in spring breeding were available in spring 1979 only.

Lambs introduced into the nursery were housed in 6'' x 24'' individual pens for the first 3 days and then placed in mixing pens. Nursery lambs were bottle fed milk replacer and then switched onto dry feed at approximately 21 days of age. Lambs were weaned from the nursery at approximately 6 weeks of age. Due to the way the experiment was designed, individual lambing performance was not documented for the low labor, annual lambing system ewes; also, weaning weights were adjusted to 42 days of age for accelerated lambing system lambs and 70 days for high labor, annual lambing and low labor, annual lambing systems. Weaning weights of all nursery lambs were adjusted to 42 days of age, (in the accelerated and high labor annual lambing systems). The low labor system did not utilize the nursery. Separate statistical analysis of accelerated lambing ewe performance allowed seasonal affects on productivity to be evaluated.

Results

No interactions among the percentage of Finn breeding and management system for ewe productivity (measured by pounds of lamb weaned per ewe per year) were detected. The high labor, annual lambing ewes weaned more pounds of lamb per year than accelerated lambing ewes or low labor, annual lambing ewes (Table 2). Although the accelerated lambing ewes weaned more lambs per year, weaning of lambs at a younger age resulted in a lighter lamb. Individual lamb weaning weights were similar for high labor, annual lambing ewes and low annual labor, lambing ewes (51 and 52 lb, respectively) but less for the accelerated lambing ewes system (32 lb). Nursery raised lambs averaged only 23 lb at weaning.

Accelerated lambing ewes averaged 1.63 exposures and 1.06 lambings per year (high labor, annual lambing ewe had a .90 lambings per year) which resulted in their advantage over annual system ewes in lambs born per year. Overall survival was greatest for high labor annual lambing ewes' lambs with accelerated lambing ewes being intermediate. The high labor, annual lambing system ewes produced the most lambs per exposure with low labor, annual lambing ewes being intermediate; and high labor, annual lambing ewes also exceeded accelerated lambing ewes for lambs weaned per lambing. Thus, the advantage of the accelerated lambing system in lambs weaned per year was made possible by multiple exposures and thus more lambings per year.

Fertility (lambings per exposure) was depressed during the fall (September) and especially spring (May) matings (Table 3). Fecundity (lambs born per lambing) was greater in high labor, annual lambing ewes than accelerated lambing ewes (Table 2) and was higher in fall-bred (2.03) than either winter-(January; 1.83) or spring-bred (1.86) ewes. Lambs resulting from fall mating had the poorest overall survival (.70 vs .74 and .78 lambs weaned per lamb born for winter and spring, respectively) despite having the best nursery survival among seasons (.80 vs .58 and .69). Overall, nursery survival was .69 lambs weaned per lamb entered into nursery.

The percentage of Finn breeding did not influence weight weaned per year (Table 2), but ½ Finn ewes did wean more pounds per lambing. Quarter-Finn ewes weaned lambs that were 3.1 lb heavier, with the advantage over ½ Finns being especially apparent in the annual systems (.9, 3.3 and 5.1 lb for accelerated lambing ewes, high labor, annual lambing ewes and low labor, annual lambing ewes systems, respectively). Half-Finn ewes had more lambs born per year, with the effect of increased Finn breeding most apparent in the annual systems. Half-Finn ewes produced .06, .29 and .20 more lambs per exposure than ¼ Finns in the accelerated, high labor, annual lambing and low labor, annual lambing systems, respectively, in part due to the advantage of ½ Finns in winter breeding (Table 3). Increased Finn breeding lowered ewe fertility in accelerated lambing (.63 vs .68 lambings per

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Table 1—Production system management criteria

Item	System[a] HIGH	MED	LOW
Lambing program	Ewes exposed to lamb three times in 2 yr. Hormonal treatment used prior to spring breeding to enhance and synchronize estrous activity. Rams used in spring breeding phototreated in 1979 only.	Annual.	Annual
Breeding	Individual sire matings in dry lots (ewes fed corn silage).	Multisire group pasture matings.	Multisire group pasture matings.
Feeding	Ewes provided with corn silage during late pregnancy and lactation.	Ewes provided with corn silage for 5 weeks postpartum.	Ewes received limited energy supplimentation
Lambing facilities	Raised slatted floor lambing barn with jug pens. (approximately 15 square ft of slatted floor space/ewe).	Open front poleshed with jug pens. (approximately 16 square ft/ewe).	Open front poleshed and pasture, no jugs. (approximately 6 square ft barn and 1.2 acres/ewes).
Preweaning	Ewes and lambs fed ad libitum in lambing facility.	Ewes and lambs in dry lot until about 30 d postpartum then maintained on pasture. (approximately .6 acres/ewe).	Lambs and ewes maintained on pasture. (approximately .9 acres/ewe).
Weaning	Lambs weaned at approximately 6 weeks of age.	Lambs weaned at approximately 10 weeks of age.	Lambs weaned at approximately 10 weeks of age.
Artificial rearing	Intensive use. Weak lambs, lambs with litter size greater than twins, or lambs orphaned prior to 35 days of age transferred to nursery.	Weak lambs, lambs from litter size greater than twins, or lambs orphaned prior to 28 days of age.	Not available.
Labor	High commitment, all phases. Lambing assistance provided.	High commitment during lambing. Lambing assistance provided.	Low commitment, all phases.

[a]HIGH, MED and LOW are intensive accelerated, intensive annual and extensive annual lambing systems, respectively

exposure for ¼ Finns) but not in the high labor, annual lambing (.91 vs .89) system, due to lower fertility of ½ Finn ewes in fall breeding (Table 3). The lower fertility of accelerated lambing ½ Finn ewes was offset by a .25 lamb per lambing advantage (Table 2).

Half-Finn ewes weaned more lambs per year than ¼ Finns although the advantage of ½ Finns for lambs weaned per exposure only occurred following winter exposure (Table 3). On a per lambing basis, ½ Finn exceeded ¼ Finn ewes by .17 weaned lambs per year. Lambs out of ¼ Finn ewes exhibited greater overall survival than lambs of ½ Finns.

Discussion

Potential lamb production advantages of the accelerated lambing system would be critically dependent upon a market for young lambs or an efficient method of raising lambs until sold as feeder or market lambs. The most lambs were generated (born and weaned) per ewe per year with the accelerated lambing system due to the opportunity for each ewe to lamb more often than once per year. However, the advantage of multiple exposures per year was offset by the lighter weights of the younger weaned lambs. Using post-

Table 2 – Summary of output per ewe by management system and percent Finn.

Trait	System[a]			Percent Finn	
	HIGH	MED	LOW	25	50
Number of ewes[b]	546	268	250	533	531
Lambs born per year	2.05	1.85	1.66	1.74	1.95
Lambs born per lambing	1.93	2.11	NA*	1.89	2.14
Lambings per exposure	.65	.90	NA*	.78	.77
Lambs weaned per year	1.55	1.46	1.18	1.35	1.45
Lambs weaned per lambing	1.45	1.71	NA*	1.49	1.66
Lambs weaned per lamb born	.75	.89	.71	.77	.75
Pounds of lamb weaned per year[c]	49.9	74.4	61.4	61.6	62.3
Pounds of lamb weaned per lambing[c]	46.6	84.5	NA*	64.0	67.1

[a]Defined in Table 1
[b]At start of study.
[c]HIGH weaning weight adjusted to 42 days of age; MED and LOW adjusted to 70 days
*NA = Not measured in LOW ewes.

weaning rate of gain values previously calculated at MARC, the estimated weight of accelerated system lambs at 18 weeks would be 85.6 pounds compared with 79.0 for high labor, annual lambing ewes and 80.0 for low labor, annual lambing ewes. Thus, accelerated system lambs were smaller at weaning due only to earlier weaning (younger age). The accelerated system ewes benefited from multiple exposures per year which counterbalanced the decreased fertility at any one mating period and led to the overall advantage of accelerated lambing ewes for lambs weaned per year. However, the 1.06 lambings per ewe per year for the accelerated lambing system was not proportional to the 63% increase in exposures per year over the annual systems.

Productivity was highest for high labor, annual lambing ewes even though this system also resulted in a number of light, 6-week-old (nursery) weaned lambs. However, high labor, annual lambing system ewes' productivity was highest even if nursery lambs had been ignored. The advantage of high labor, annual lambing ewes over accelerated lambing ewes was due to lamb weaning age and over low labor, annual lambing ewes in part due to increased lambs born per ewe per year. Whether the advantage of high labor, annual lambing ewes over low labor, annual lambing ewes for lambs born was due to better fertility or greater litter size could not be tested in this experiment.

The weight of lamb weaned per year was similar for the two maternal lines due to the counteractive effects of an advantage of 1/2 Finn ewes for lambs weaned per year and a disadvantage of ½ Finns for weight per weaned lamb. Half-Finn ewes were able to wean more pounds of lamb per ewe lambing due to higher litter size. The lower fall fertility of ½

Finn ewes yielded an advantage to the ¼ Finn ewes for overall fertility in the accelerated system but not the high labor, annual lambing system. The increased litter size of ½ Finn ewes and probably the availability of the nursery led to the overall advantage of ½ Finn ewes in lambs weaned. The greater survival of lambs from ¼ Finn ewes was presumably caused by smaller litters and associated increased lamb vigor and size.

Weaning weights were heavier for lambs from ¼ Finn ewes, especially in the low labor, annual lambing system. The larger litters of ½ Finn ewes were apparently detrimental to individual lamb growth under the extensive conditions of the low labor, annual lambing system especially because all lambs remained on the ewe. Half-Finn ewes have been previously shown to be less advantageous for lamb production compared to ¼ Finn when environmental conditions are stressful.

In general, interactions among the percent of Finn breeding and the production system for ewe productivity (measured by pounds of lamb weaned per ewe per year) were not detected. Thus, ewe line effects on pounds of lamb weaned per ewe per year were similar regardless of their breeding and management system. Accelerated lambing produced an advantage in lambs weaned per year but early weaning resulted in a younger (smaller) lamb which would require additional feed to reach market weight. However, accelerated lambing ewes did not increase lamb output in proportion to increased exposures compared to the annual systems. Quarter and ½ Finn ewes produced similar pounds of weaned lamb per year; thus, increased Finn breeding did not improve productivity, even with the use of nursery facilities.

Table 3—Summary of output per ewe in the accelerated system by season and percent Finn x season

Trait	Percent Finn, season[a]					
	25%, Fall	50%, Fall	25%, Winter	50%, Winter	25%, Spring	50%, Spring
Lambings per exposure	.69	.59	.82	.83	.56	.52
Lambs born per exposure	1.32	1.29	1.40	1.62	1.01	1.01
Lambs weaned per exposure	1.01	.98	1.12	1.28	.79	.78
Pounds weaned per exposure	33.2	29.9	33.4	38.3	25.1	25.3

[a]Season of exposure to rams: Fall = September; Winter = January; Spring = May.

Relative Importance of Performance Traits for Efficiency of Market Lamb and Wool Production

C.T. Wang and G.E. Dickerson[1]

Introduction

Breeding programs to improve efficiency of market lamb and wool production can be most effective when the emphasis placed upon different performance traits in selecting breeding stock considers the relative economic importance of improvement in each trait, as well as trait differences in degree of genetic control and the genetic associations among traits. A useful measure of economic efficiency is feed input cost per unit of output value, because feed is the major input in sheep production and other variable costs tend to be proportional to feed costs. It would be very difficult and expensive to conduct experiments to directly measure the effect of genetic changes in each performance trait on input/output efficiency. However, by using the published information from many past experiments with sheep, it was possible to develop a computer program capable of predicting effects of alternative genetic changes on production efficiency. This program was used to predict the effect on feed input per unit of output value from genetic changes in nine traits of ewe and lamb performance, for a pure breeding sheep production system, under optimum annual lambing as well as shorter lambing interval management.

Procedures

Feed input was measured as total pounds of digestible nutrients (TDN), adjusted for changes in cost when an increase in performance required a higher protein content (CP/TDN) in the feed. Market output value was measured in terms of either live (BW) or carcass lean (CL) weight of lambs marketed at 30 weeks of age, plus the equivalent value from cull ewes and wool sold. Weight of cull ewes was included at one-third the value of market lambs, and clean wool at 2.08 times live lamb weight but equal to lamb carcass lean weight. Efficiency for a sheep production system was expressed as weight of feed input per unit of output value equivalent weight of live lamb (TDN/BW) or lamb carcass lean (TDN/CL). All inputs of feed and outputs of lambs, ewes and wool were calculated for straightbred flocks of ewes ranging in ages at lambing from 1 to 5 years, after which surviving ewes were marketed.

The genetic levels of performance examined were 71, 82 and 94 lb for mature ewe weight, 66, 71 and 76% of lean in mature weight, 1.2, 1.75 and 2.30 oz/week of clean wool growth by a 71 lb ewe; 83, 87 and 90% survival of lambs to weaning age of 11 weeks; 72, 85 and 98% lambing of all ewes mated; earliness of sexual maturity at 0, 50 and 100% of standard difference in ewe fertility between 8 month and mature ages; 1.25 to 2.85 lambs born per 2 year old ewe lambing; 3.3, 6.0 and 8.6 lb of milk per day from 71 lb ewes, and 72, 132 and 192 days for length of seasonal fertility of mature ewes. Comparisons of genetic levels for each trait were made for specific combinations of levels for other traits, to examine combined effects of changes in groups of traits. Effects of genetic changes in reproductive traits were examined under both optimum spring lambing and management for lambing at 7 or 8 month intervals.

The computer model calculates growth from birth to mature

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body weight and the feed intake required to maintain normal body condition during growth, gestation, lactation and for varying numbers of lambs born and reared. Ewes are culled after any 13 months of continuous infertility. The model also can examine effects of restricted feeding after weaning and during early pregnancy, with or without flushing before breeding, and creep feeding of lambs.
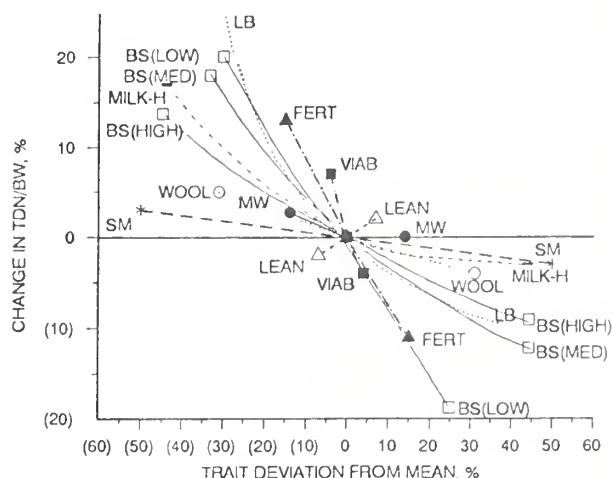

Figure 1 – Simulated changes in feed input per unit of live lamb equivalent output value (TDN/BW, %) under annual lambing in straightbred flocks for genetic deviations of performance traits (%) from intermediate population means. Deviations shown for breeding season length (BS) are for planned 7.2 mo intervals between lambings of same ewe (73 d intervals between breeding periods) at high, medium and low levels of other reproductive traits. MILK-H is for 2.85 lambs born per lambing. See text for definitions of traits.

Results

The general percentage changes in efficiency (feed input/live lamb output equivalent, TDN/BW) from the percentage changes studied for each of the nine traits are shown in Figure 1. The effect of a given percentage change was greatest for lamb viability (VIAB) and ewe fertility (FERT), but the possible total amount of change was greater for lambs born per lambing (LB) or for total length of breeding season (BS). Effects on efficiency were relatively small from improvements in wool growth rate (WOOL), mature weight (growth rate, MW) or earliness of sexual maturity (SM). Notice that the effect on efficiency from a given percentage change in a trait was greater in the lower than in the upper range for each trait, especially for changes in lambs born (LB), milk production (MILK) and mature weight (MW). Also note that sheep with a longer breeding season would improve efficiency proportionally more when lambs born, fertility and sexual maturity are at lower levels. Increasing body lean content (LEAN) would slightly increase, rather than reduce, feed cost of live lamb equivalent output, because of the increased maintenance requirements for leaner animals. However, it would decrease feed costs for lamb carcass lean output.

Table 1 – Mean percentage change of input/output (TDN/BW or TDN/CL) per 10% increase in trait mean[a], under annual lambing

Trait	Lambs born – 1.25		Lambs born – 2.05		Lambs born – 2.85	
	TDN/BW	TDN/CL	TDN/BW	TDN/CL	TDN/BW	TDN/CL
Mature weight	-3.4	-3.3	-0.9	-1.0	0.3	0.4
Lean content	3.2	-1.2	2.8	-2.3	2.7	-2.6
Wool growth	-2.8	-3.2	-1.5	-1.7	-1.2	-1.3
Viability	-18.9	-20.4	-14.6	-15.3	-13.8	-14.6
Sexual maturity	-0.9	-0.9	-.6	-.6	-.6	-.6
Fertility	-10.7	-10.0	-8.0	-7.7	-7.7	-7.3
Milk yield	-0.9	-1.0	-1.5	-1.6	-1.9	-2.1

[a]See Figure 1 for range in effect of each trait and text for definitions of traits and of TDN/BW or TDN/CL. Increased protein required in TDN would make reductions in cost slightly less than shown, especially for LB and MILK

Table 2 – Mean percentage change of input/output (TDN/BW or TDN/CL) per 10% increase in lambs born or lean content for differing ewe mature weight, under annual lambing[a]

Trait	Mature weight = 132 lb		Mature weight = 154 lb		Mature weight = 176 lb	
	TDN/BW	TDN/CL	TDN/BW	TDN/CL	TDN/BW	TDN/CL
Lambs born	-7.7	-8.1	-6.8	-7.4	-6.1	-6.9
Lean content	2.8	-2.3	3.0	-2.0	3.0	-1.7

[a]See text for definitions of TDN/BW and TDN/CL.

Table 3 – Percent reduction in input/output (TDN/BW) under yearly (Y), 4 month (A) and 73 d (S) breeding intervals (12, 8 and 7 month lambing intervals) for 10% increases in lambs born (LB), fertility (FERT), and sexual maturity (SM) at three levels of breeding season length (BS), and for 10% increase in BS at LOW, MEDIUM and HIGH levels for LB, FERT and SM[a]

Other traits	10% increase in	Y	A	S
BS[b]				
192	LB	-9.5	-5.5	-5.0
132		-9.7	-6.7	-5.9
72		-10.3	-8.8	-9.4
192	FERT	-8.2	-7.5	-4.9
132		-8.2	-11.8	-7.8
72		-8.2	-19.3	-19.3
192	SM	-1.3	-.8	-.5
132		-1.3	-1.5	-1.0
72		-1.3	-2.5	-2.5
Reproduction[c]				
LOW	BS	-.9	-11.3	-17.0
MED		-.7	-4.2	-5.2
HIGH		-.7	-2.2	-2.7

[a]Increased cost/lb TDN-at higher performance levels from higher crude protein (CP/TDN) requirements would make these reductions in TDN/BW only very slightly lower than shown. See Table 4 and text.

[b]Base levels of traits are: LB = 1.85, FERT = .85 and SM = 0

[c]LOW: LB = 1.25, FERT = .72, SM = 0
MED: LB = 1.85, FERT = .85, SM = .5
HIGH: LB = 2.45, FERT = .98, SM = 1.0

The relative importance of the nine different performance traits studied can be expressed as the average percentage change in feed input/body weight (TDN/BW) or feed input/carcass lean (TDN/CL) output from a 10% improvement in each trait (Tables 1,2 and 3). The effect of changes in each trait also depends upon the genetic level of other traits, such as lambs born (Table 1), length of breeding season (Table 3) and other reproductive traits (Table 4), and on management of the interval between lambings (Tables 3 and 4).

The proportional effect of a 10 percent improvement would be nearly the same in feed cost of live weight (TDN/BW) as in feed cost of lean (TDN/CL) output (Tables 1 and 2) for all traits except body lean content itself. A 10% increase in body lean content increased TDN/BW about 3%, but reduced TDN/CL more at higher than at low levels of lambs born (-2.6 vs -1.2%), but similarly at high and low levels of mature weight (-1.7 vs -2.3%).

Reduction in feed cost/live weight at low to high levels of lambs born (Table 1) was easily greatest for 10% improvement in lamb viability (-20 to -14%) and ewe fertility (-11 to -7%), much less for wool growth (-3 to -1%), mature weight (-3 to 0%), milk yield (-1 to -2%) and sexual maturity (-.9 to -.6%).

Increasing the number of lambs born (LB) by 10% (Table 3) was nearly as important as a 10% increase in fertility under annual lambing, but was proportionately less under accelerated 8 or 7 month lambing intervals (-5 vs -9% vs -10%) or with long vs short breeding season sheep (-5 vs -9%). The proportional effect of 10% higher fertility was reduced by shorter lambing intervals for long-season sheep (-5 vs -8%) but increased for short-season sheep (-19 vs -8%). A 10% genetic increase in length of breeding season would have little effect (-1%) on feed cost of live lamb output equivalent under annual lambing management (Table 3), but the reduction in costs under 8 or 7 month lambing intervals would range

from -11 or -17% for sheep of low reproductive rate to -2 or -3% for highly prolific sheep. The effect of 10% earlier sexual maturity under 7 month vs 12 month lambing intervals also would be proportionately less for long-season (-.5 vs -1.3%), but more for short-season sheep (-2.5 vs -1.3%).

The expected effect on efficiency of shorter lambing interval management for short to long breeding season sheep of low to high prolificacy is shown in Table 4. The shorter 8 or 7.2 month (A or S) lambing intervals would be expected to reduce feed costs per unit of live lamb equivalent output sharply only for sheep with moderate to long (132 to 192 day) breeding seasons, and proportionately more so for the least prolific (-22 to -53%) than for the most prolific (-15 to -24%) ewes. Feed costs could be increased substantially by more frequent lambing intervals for lowly prolific, short season sheep, even if infertile ewes are culled sooner than under annual lambing, and especially if the extra labor of more frequent breeding and lambing seasons were added to input costs.

The management alternative of restricted feeding of ewes during early pregnancy and after weaning their lambs did not reduce expected feed input per unit of output, because ewes ate more to regain normal weight when restriction was ended. Thus feed restriction would be profitable only if cost per unit of restricted feed is substantially lower than for the feed used during late pregnancy and lactation. The practice of flushing (more and better feed prior to breeding) reduced total feed costs/unit output only for restricted-fed ewes, and more for low than for high lambing rates (-6 vs -4%). Creep feeding of lambs was helpful only for prolific ewes of low milking ability (up to -12% reduction of feed/unit output).

The results presented here provide first approximations for the relative economic importance of ewe and lamb performance traits, for use in developing the most effective selection programs for straightbred lamb and wool production systems in North America. This approach can be extended to see how relative importance of traits would differ for breeds used in crossbreeding primarily to sire market lambs as compared with those used to produce mothers of market lambs. In general, relative importance of traits for maternal breeds is expected to be similar to those reported here for straight breeding systems. However, the many traits affecting ewe reproductive rate (fertility, sexual maturity, lambing rate, milk yield, length of breeding season and wool) would be of little importance in terminal sire breeds, compared with mature weight or growth rate, leanness and lamb viability. The relative importance of traits also would change in other countries, especially where markets dictate very different relative values for wool and meat.

Table 4 – Effect of breeding season length (BS) on input/output (TDN/BW) for yearly (Y), 4 month (A) and 73 day (S) breeding intervals, at HIGH, MEDIUM (MED) and LOW combinations of lambs born (LB), sexual maturity (SM) and fertility (FERT)[a]

BS d	LB No.	SM %	FERT %	Y TDN/BW kg/kg	Y %BS -132d	Y % MED	Y CP/TDN[b]	A TDN/BW kg/kg	A %BS -132d	A % MED	A %Y	A CP/TDN	S TDN/BW kg/kg	S %BS -132d	S % MED	S %Y	S CP/TDN
192	2.45	100	98	13.45	99	74	.141	10.72	92	87	80	.142	10.18	90	89	76	.143
132				13.62	100	75	.141	11.60	100	82	85	.140	11.25	100	86	83	.141
72				14.34	105	75	.140	13.01	112	73	91	.138	12.79	114	73	89	.138
192	1.85	50	85	18.07	99	100	.137	12.33	87	100	68	.139	11.41	87	100	63	.141
132				18.27	100	100	.137	14.23	100	100	78	.137	13.15	100	100	72	.138
72				19.15	105	100	.136	17.74	125	100	93	.134	17.59	134	100	92	.134
192	1.25	0	72	34.74	99	192	.132	19.88	72	161	57	.134	16.49	75	145	47	.136
132				35.26	100	193	.132	27.65	100	194	78	.130	22.08	100	168	63	.133
72				37.60	107	196	.131	48.20	174	271	128	.127	50.45	228	287	134	.128

[a]See text for definitions of input/output efficiency (TDN/BW) and for BS, LB, SM and FERT.
[b]Cost/lb TDN increases about 23% for each .001 increase in content of crude protein (CP/TDN) required in diet.

Effect of Fish Meal and Dietary Protein Level on Lactation Performance of Half-Finnsheep Crossbred Ewe Lambs

Wilson G. Pond and Mike H. Wallace[1]

Introduction

Previous research work at MARC has indicated that when lactating ewe lambs are full-fed corn silage based diets, they may not respond well to higher levels of dietary protein. This seems to be caused by the ewe being unable to eat enough dry matter when corn silage makes up too high a proportion of the diet.

More recent work indicates that when dietary protein is supplemented above what is recommended by the National Research Council (1985), it may actually be detrimental to lactating ewe performance and nursing lamb weight gain. This was observed when soybean meal was added at the expense of corn to increase the protein concentration in the diet. Soybean meal is a substance that the rumen of the sheep can degrade very well, and in the process ammonia nitrogen is produced. Ammonia nitrogen is synthesized by the rumen microflora as amino acids and protein. When the lower weight gain of nursing lambs was observed as previously noted, scientists felt this could indicate an overload of ammonia produced in the ewes' rumen caused by the ewes' eating more of the highly degradable protein than they needed to maintain lactation.

The current experiment compared ewes' lactation performance when they were fed soybean meal (which is highly degradable in the rumen), and fish meal. Fish meal is considered to be relatively insoluble in the rumen, and is called a "bypass protein" because it is primarily digested in the intestinal tract after leaving the rumen. If a positive response in lactation performance was observed (increased lamb weight gain) by ewes on the fish meal diet, it would be a positive statement in favor of the bypass protein. If neither the soybean meal or the fish meal supplementation showed a significant increase in ewe performance, then this would suggest that how the protein is digested is not an important factor in lactating ewe performance.

Procedure

One hundred-twenty ½ Finnsheep, ¼ Dorset, ¼ Rambouillet ewe lambs were estrus synchronized and mated with tup mark collection for one heat cycle between December 9 and December 14, 1988. The resulting lactating ewes with lambs were sorted by type of rearing (singles and twins), ewe weight and ewe age (months), and placed on four replicates of the following four diets (see Table 1 for composition):

Diet 1—Corn-soybean meal—normal protein (13.5%)
Diet 2—Corn-fish meal—normal protein (13.5%)
Diet 3—Corn-soybean meal—high protein (16.3%)
Diet 4—Corn-fish meal—high protein (16.3%)

Ewe and lamb weights at the first day of the experiment (2 to 7 days after lambing) and at 2, 4, 6, and 8 weeks old were recorded. Ewes were fed all they wanted to eat of the pelleted rations. Ewe feed and lamb creep feed consumption were recorded every 2 weeks. A blood sample was taken from four ewes in each pen (randomly selected within breed and type of rearing) at the first day and during the 4th and 8th weeks (weaning) for a measurement of blood serum urea nitrogen, total protein and albumin, as a measure of protein status. Data were analyzed (by SAS least-squares means analysis of variance) with pen averages as the experimental unit for each trait.

[1]Pond is a research animal scientist, Children's Nutrition Research Center, Houston, TX (formerly research leader, Nutrition Research Unit, MARC); Wallace is sheep operations manager, MARC.

Table 1—Composition of pelleted diets (percentage)

| | Protein source and level | | | |
| | Soybean meal 13% protein (SM13) | Fish meal 13% protein (FM13) | Soybean meal 16% protein (SM16) | Fish meal 16% protein (FM16) |
Ingredient				
Alfalfa	20	20	20	20
Corn grain	50.392	52.392	43.392	47.392
Soybean meal			13	
Fish meal		4		9
Beet pulp	20	20	20	20
Vitamin premix A,D,E	.05	.05	.05	.05
Steam bone meal	.5	.5	.5	.5
Trace mineralized salt	.5	.5	.5	.5
Rumensin, 60	.008	.008	.008	.008
Durabond	2.5	2.5	2.5	2.5
Auremycin, 60	.05	.05	.05	.05
Total, %	100.0	100.0	100.0	100.0
Chemical Analysis				
Dry matter (DM), %	89.6	89.6	89.7	89.8
TDN, % of DM (calculated)	74.8	74.0	74.8	73.2
Crude protein, % of DM	13.5	13.4	16.3	16.3
Calcium, % of DM	.62	.84	.64	1.12
Phosphorus, % of DM	.36	.46	.39	.60

Table 2—Ewe daily weight gain by 2-week periods, pounds

	SM13	FM13	SM16	FM16	Singles (S)	Twins (T)	Treatment Differences
No. of pens	4	4	4	4	8	8	
Week 0-2	.17	.18	.16	.20	.13	.23	S < T
2-4	.06	.05	.06	.02	.04	.05	FM < SM
4-6	.05	.03	.06	.06	.05	.05	
6-8	.02	.06	.01	.03	.02	.04	
Overall 0-8 wk	.07	.08	.08	.08	.06	.10	S < T

Table 3—Ewe daily feed consumption by 2-week period, lb

	SM13	FM13	SM16	FM16	Singles (S)	Twins (T)	Treatment Differences
No. of pens	4	4	4	4	8	8	
Week 0-2	6.24	6.24	6.31	6.57	6.20	6.48	S < T
2-4	6.26	6.00	5.60	7.45	7.08	5.58	S > T
4-6	7.41	7.21	8.64	6.28	6.46	8.29	S < T
6-8	7.78	8.27	8.42	8.40	7.72	8.71	
Overall, wk 0-8	6.92	6.92	7.08	7.17	6.86	7.19	

Table 4—Blood serum constituents of ewes fed fish meal or soybean meal in a 13 or 16% protein lactation diet

	SM13	FM13	SM16	FM16	Singles (S)	Twins (T)	Treatment Differences
No. of pens	4	4	4	4	8	8	
Urea nitrogen, mg/100 mL							
Week 4	18.4	19.8	16.2	20.5	19.3	18.1	FM > SM
Week 8	14.0	20.5	12.0	17.0	16.3	15.4	FM > SM 16 > 13
Total protein, g/100 mL							
Week 4	7.0	6.6	6.6	6.8	6.8	6.8	
Week 8	7.5	7.0	7.0	6.9	7.1	7.1	FM > SM
Albumin, g/100 mL							
Week 4	3.4	3.3	3.3	3.3	3.4	3.3	
Week 8	3.8	3.6	3.7	3.4	3.7	3.6	FM > SM

Table 5—Lamb daily weight gain by two-week periods, pounds

	SM13	FM13	SM16	FM16	Singles (S)	Twins Combined (T)	Treatment Differences
No. of pens	4	4	4	4			
Week 0-2	.12	.12	.11	.12	.10	.14	S < T
2-4	.09	.08	.10	.09	.07	.11	S < T
4-6	.11	.10	.16	.12	.09	.15	S < T
6-8	.12	.12	.17	.12	.09	.17	S < T
Overall, 0-8 wk	.11	.11	.13	.11	.09	.14	S < T

Results

Ewe weight gain was not affected by diet, except during the 2nd to 4th weeks when the ewes fed fish meal gained less than the ewes fed soybean meal (Table 2). Because there was no real effect of diet on ewe weight gain at other times, and over the entire 8-week lactation period, scientists felt that feeding a dry pelleted diet containing 16% protein is not excessive for ewe lactation weight gain. Also the source of protein: soybean meal, highly degradable in the rumen; or fish meal, a rumen bypass protein; did not appear to be an important factor in ewes fed dry pelleted corn-alfalfa-type diets. Ewes nursing twins gained significantly faster during the first 2 weeks of lactation than those nursing singles. Although there was no diet effect in later lactation, the early difference was still noticeable when the overall 8-week lactation period was taken into consideration. This effect appeared to be due to greater feed consumption during the first 2 weeks by ewes nursing twins compared with those nursing singles (Table 3). There was no affect of dietary protein source or level in ewe feed consumption overall or during 2-week time intervals. Blood serum urea nitrogen concentration was higher at 4 and 8 weeks and serum total protein and albumin concentrations were higher at 8 weeks in ewes fed fish meal than in those fed soybean meal (Table 4). This suggests that the usage of fish meal protein for blood protein synthesis was greater than that of soybean protein, although the difference was not related to ewe weight gain

or feed consumption. Blood serum urea nitrogen was greater at 8 weeks in the ewes fed 16% compared with 13% protein, which suggests that 16% protein may be greater than the lactating ewe's need for protein, but not enough to create clinical signs of ammonia toxicity. Lamb weight gain (Table 5) and creep feed consumption (Table 6) were not affected by maternal lactation diet, nor was creep feed consumption different for twins than for singles (Table 6). As expected, twin (combined) weight gain was greater than single lamb weight gain at each time interval and overall.

Because the fish meal had no affect on ewe or lamb performance when compared to the soybean meal, and the 16% protein did not improve either ewe lamb weight gain or feed consumption, the current level of protein recommended by National Research Council (1985) for the lactation diet of ewes seem to be adequate. It also seems that no beneficial effect can be expected from substituting fish meal for soybean meal. Furthermore, because there was no effect of diet on performance when they were nursing twins compared with singles, it seems that a 13% protein pelleted lactation diet composed of corn, alfalfa, and soybean meal properly supplemented with minerals and vitamins meets the nutritional needs of lactating ewe-lambs nursing twins, under the conditions imposed in this experiment.

Table 6—Lamb daily feed consumption by 2-week period, pounds

	SM13	FM13	SM16	FM16	Singles	Twins
No. of pens	4	4	4	4	8	8
Week 2-4	.03	.03	.04	.03	.04	.03
4-6	.05	.02	.06	.05	.05	.04
6-8	.08	.07	.09	.07	.08	.08
Overall, wk 0-8	.04	.03	.04	.04	.04	.04

Androgenized Ewe Lambs

John Klindt, Thomas G. Jenkins and J. Joe Ford[1]

Introduction

Males of most species of mammals are larger than females and their carcasses are leaner. This is true for the primary meat producing ruminant species, cattle and sheep. The greater growth rate and leaner carcass composition exhibited by the males, whether intact or castrated, is the result of gonadal steroids such as testicular androgens, testosterone and its metabolites. These steroids act through sexual differentiation and activation of specific physiological processes.

Males have both X and Y sex chromosomes, whereas females have only X sex chromosomes. These chromosomes determine genetic sex. Genetic sex of the individual is determined at conception and cannot be altered. Testicles in males are the consequence of genetic determination of sex. The actions of gonadal steroids, primarily testosterone in the male and estrogen in the female, acting through differentiation and activation, alter developmental and physiological processes which determine the sexual appearance or phenotypic sex of the individual. The development of sexual characteristics generally occurs during a specific time during fetal development. Sexual development for either male or female characteristics causes permanent changes in physiological processes and requires presence of the steroid only during the time of differentiation. Sexual activation requires continued presence of the active gonadal steroid. If the steroid is removed, the physiological process is no longer activated. Normally, sexual differentiation is toward masculine traits and occurs due to internal production of testosterone by the fetal testicles. Lack of production of testosterone by the testicles of genetic males during fetal development results in the development of individuals lacking masculine appearance. During fetal development both males and females have the ability to respond to testosterone, that is, to be differentiated. However, normally, only males are masculinely differentiated because only the testicles produce testosterone in sufficient quantities to cause differentiation. Examples of differentiation and activation include: androgen induced differentiation required for development of the penis and scrotum in males and estrogen activation of processes required for expression of heat in females.

Modification of gonadal steroid secretion has long been used to alter rate and composition of animal growth. Castration of males of most meat animal species results in animals which produce a fatter carcass, which until recently was the more desired product due to demand for animal fats. Gonadal steroids have been administered to improve rate and composition of meat animal growth. Diethylstilbestrol (DES) was a steroid product used in the 1950s and 60s. Products containing estradiol, progesterone, trembolone acetate (a synthetic androgen) and zeranol (a synthetic estrogen) are currently used in meat animal production. These methods alter the concentrations of gonadal steroids circulating in the animal's system and, thus affect growth through activational actions. Once the source of the gonadal steroid is removed its effect on growth is removed.

The objectives of the present studies were to determine if the growth characteristics of ewe lambs could be sexually

altered during early fetal development to be more like those of males, establish a procedure for most effective administration of the androgen, and gain understanding of the mechanism(s) of the animal's growth response to androgen administered before birth. To accomplish this an androgen (testosterone cypionate) was administered to pregnant ewes during early pregnancy. The administered androgen crossed the placenta and resulted in significant concentrations of androgen in the developing female offspring. These significant concentrations of androgens in the developing female offspring caused masculinization, or male sexual differentiation, of many aspects of the physiology of those ewe lambs.

Growth Performance and Treatment Effectiveness

The initial studies sought to determine if growth characteristics of ewe lambs could be modified by exposure to significant quantities of androgen during early fetal development. Pregnant crossbred ewes which had been mated at an induced estrus were administered the androgen testosterone cypionate (Depo-Testosterone, 200 mg in l ml cottonseed oil, im), on approximately 32 to 39 days, 40 to 47 days, 54 to 61 days, 68 to 71 days, and 82 to 89 days after mating. After weaning, a feeding trial was initiated with 36 to 45 lambs from each sex (ram, wether, ewe) and dam treatment (control, exogenous androgen during pregnancy) group. At the end of the 84-day feeding trial the lambs were slaughtered and weights of carcass components recorded. The carcasses were ground and chemical composition determined.

Average daily gains of the rams, regardless of dam treatment, were greater than those of wethers or control ewes (Figure 1). Ewe lambs from androgen treated dams (androgenized ewe lambs) had average daily gains approximately 12% greater that those of the control ewe lambs. Efficiency of gain (gain/feed) of rams and wethers were similar, approximately 23%, and considerably greater than that of control ewe lambs, 20%. Efficiency of gain in androgenized ewe lambs, 25.4%, was greater than in any other group. Improvement in efficiency of gain in ewe lambs treated with androgen prenatally, treatment was 28% over that of the control ewe lambs. Prenatal androgen treatment had significant effects on carcass content of fat and water (Figure 2). Carcasses of androgenized ewe lambs contained 15% less fat and 13.3% more water. These differences suggest that the physiological maturity of the androgenized ewe lambs was less at slaughter than that of the control ewe lambs.

An initial question that followed demonstration of the effectiveness of prenatal androgen exposure in inducing masculine growth characteristics in ewe lambs concerned how to effectively administer the androgen. When is the best time during gestation for androgen to be administered in order to obtain the desired response in growth performance? In a second trial, pregnant ewes were assigned to four treatment groups: #1, control, no administration of testosterone cypionate; #2, five injections (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at 35 to 41 days, 42 to 48 days, 49 to 55 days, 63 to 69 days and 77 to 83 days after mating; #3, four injections (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at 35 to 41 days, 42 to 48 days, 49 to 55 days, and 63 to 69 days after mating; #4,

[1]Klindt is a research physiologist, Nutrition Research Unit; Jenkins is a research animal scientist, Production Systems Unit; Ford is an animal research physiologist, Reproduction Research Unit.
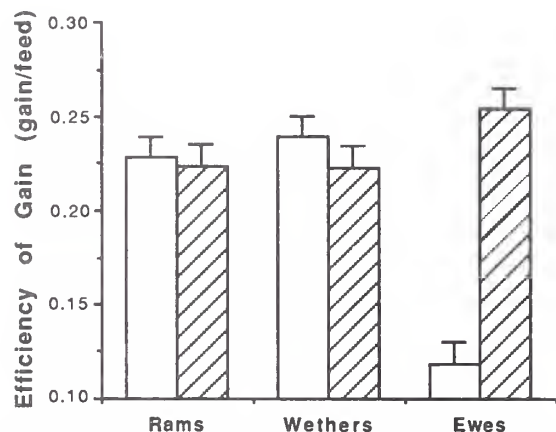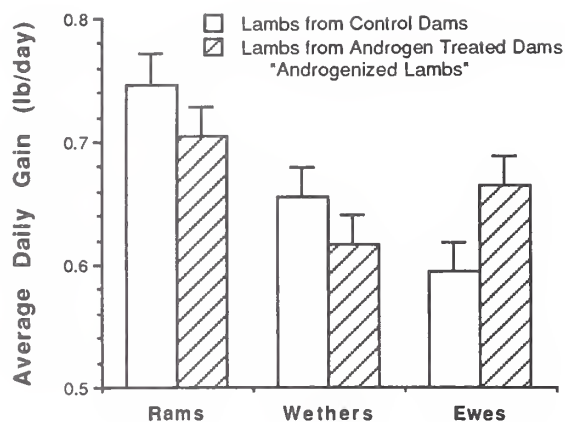
Figure 1 – Growth performance measures in lambs born to dams which received androgen during pregnancy.

three injections (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at 35 to 41 days, 42 to 48 days, and 49 to 55 days after mating. Lambs were weaned at an average age of 73 days and placed in a single pen and growth rate determined through approximately 115 lb live weight. Weights were obtained at 2 week intervals for determination of average daily gain.

Prenatal exposure to androgen as administered in this trial significantly increased the rate of gain of the androgenized ewe lambs. There were no significant differences in the growth rates among the three androgenized ewe lamb groups: dams received three, four or five injections of the androgen. These results indicate that three injections of the androgen administered during week 7, 8 and 9 of gestation were as effective in causing masculine growth response, as measured by average daily gain, as four or five injections which included the same period of pregnancy.

A subsequent trial sought to further define the window for effective administration of androgen. Pregnant ewes were assigned to four treatment groups: #1, control, no administration of testosterone cypionate; #2, one injection (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at 42 to 48 days after mating; #3, two injections (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at 42 to 48 days and 49 to 55 days after mating; #4, three injections (200 mg testosterone cypionate in 1 ml cottonseed oil/injection) at day 42 to 48 days, 49 to 55 days, and 56 to 62 days after mating. None of the male lambs were castrated. Lambs were weaned at an average age of 73 days and placed in a single pen and then growth rate was determined through approximately 115 lb live weight. The sheep were weighed at 2 week intervals for determination of average daily gain.

There was a steady increase in the growth rates of the female offspring with increasing numbers of androgen injec-

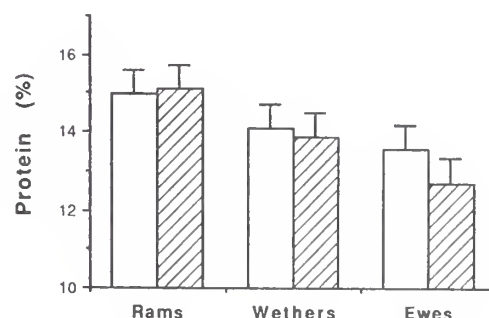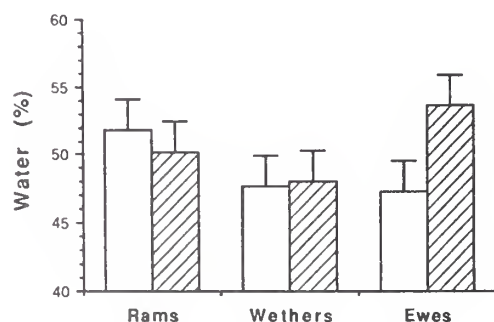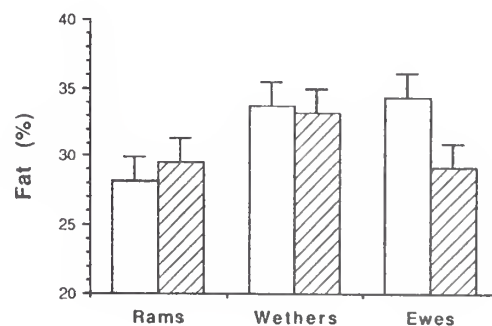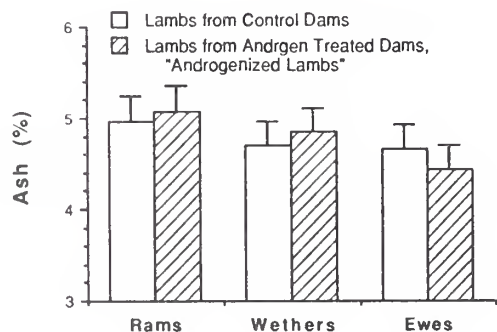**Figure 2** – Carcass composition of lambs born to dams administered androgen during pregnancy.

tions at weekly intervals. The androgenized ewe lambs from dams which had received three injections of androgen grew faster than those from dams which received zero, one, or two injections of androgen. These results indicate that a minimum of three injections of the androgen, 200 mg testosterone cypionate in cottonseed oil per injection, at weekly intervals are required to induce the masculinized growth response.

Mechanisms

Scientists wanted to better understand the mechanism(s) by which administration of the androgen to pregnant ewes alters the growth of the ewe lambs postweaning. They believe this may provide additional strategies for control of growth rate and carcass composition. Groups of ewe lambs born to untreated or androgen treated dams were assigned to two treatments, intact and ovariectomized (ovaries surgically removed) in a growth trial. The lambs were ovariectomized after weaning, placed in individual pens, and their growth rate and feed consumption were measured. At two lamb ages during the trial blood samples were collected at 15 minute intervals for 8 hours for measurement of growth hormone or somatotropin and prolactin, two major growth regulating hormones from the pituitary.

Growth performance, rate and efficiency, in the androgenized ewe lambs was greater than that measured in the control ewe lambs (Table 1). Surprisingly, ovariectomy of androgenized ewe lambs diminished the growth response. Ovariectomy had no effect on growth performance in the control ewe lambs. These data indicate that ovaries of the androgenized ewe lambs produce a factor which is needed for the superior growth performance which was observed. What the ovaries produce could be different in the androgenized ewe lambs than in the control ewe lambs. It is also possible that production of this ovarian factor is not different between the two groups but the response to the factor is different. Recent results from studies with rats suggest that the growth response to gonadal steroids is different according to sex.

The blood samples collected at 85 and 136 days of age indicated absolutely no differences due to dam treatment or ovariectomy in the patterns of growth hormone or prolactin secretion. The improved growth performance of androgenized ewe lambs is not due to increased pituitary production of these growth regulating hormones.

Wool Growth

In the initial growth study where carcass measures were taken, it was noted that weights of pelt + fleece from androgenized ewe lambs was significantly heavier than those from control ewe lambs (Figure 3). Because of this, fleeces were collected for determination of wool production by the androgenized ewe lambs. Fleeces were collected from androgenized ewe lambs and control ewe lambs. These fleeces were shipped to Dr. Chris Lupton, Texas A & M Sheep and Goat Experiment Station, San Angelo, Texas, for processing. While androgenized ewe lambs had produced heavier weights of the pelts + fleece, there were no differences due to prenatal androgen treatment in the weight of the fleeces only.
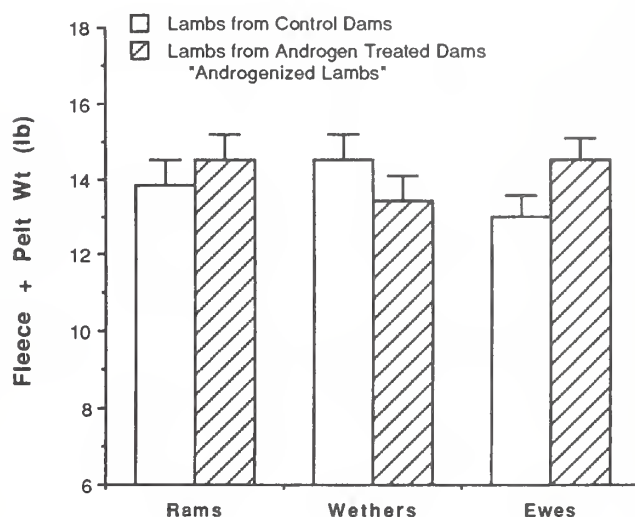

Figure 3 – Fleece + pelt weights in lambs born to ewes administered androgen during pregnancy.

Table 1—Least-squares means and standard errors for growth performance of ewe lambs

Treatment group	n	Average daily gain (kg/d)	Feed consumption (kg/d)	Efficiency
Control-intact	6	0.23 ± 0.01^b	0.96 ± 0.04^b	0.31 ± 0.01
Control-ovx	7	0.25 ± 0.01^b	$1.02 \pm 0.03^{b,c}$	0.32 ± 0.01^b
Androgenized-intact	7	0.30 ± 0.01^c	1.10 ± 0.03^c	0.36 ± 0.01^c
Androgenized-ovx	6	0.24 ± 0.01^b	0.97 ± 0.04^b	$0.34 \pm 0.01^{b,c}$

[a]Efficiency = $\dfrac{\text{In Body wt} - \text{In Intercept}}{\text{In Cumulative Feed Intake}}$

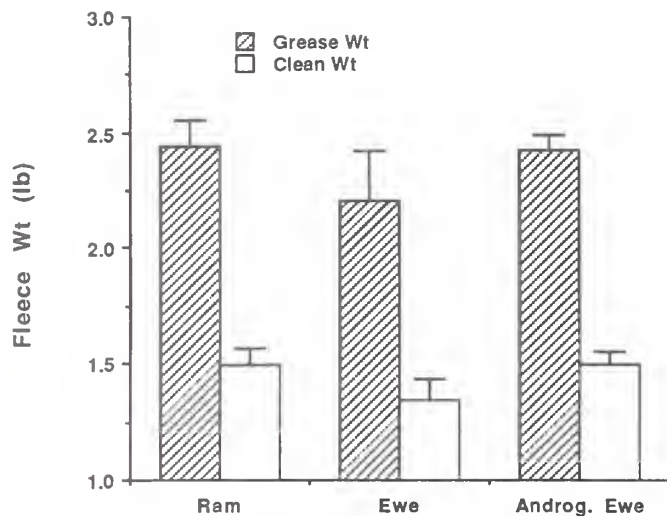[b,c]Values within a column with common superscripts are not different (P < 0.05)

Figure 4 – Weights of fleeces from lambs born to dams administered androgen during pregnancy.

Summary

Administration of three injections of androgen (testosterone cypionate, 200 mg/injection) to pregnant ewes at weekly intervals initiated between 6 to 8 weeks after mating produces ewe lambs which have masculinized growth characteristics. These androgenized ewe lambs grow faster and more efficiently and produce carcasses containing less fat, but are infertile and unsuitable for replacement ewes. To improve meat production of ewe lambs, pregnant ewes should be treated weekly for 3 weeks with 200 mg/treatment of testosterone cypionate beginning at 6 to 7 weeks of gestation.

References

Klindt, J., Jenkins, T. G. and Ford, J. J. Prenatal androgen exposure and growth and secretion of growth hormone and prolactin in ewes postweaning. Proc. Soc. Exp. Biol. Med. 185:201-205. 1987.

Jenkins, T. G., Ford, J. J. and Klindt, J. Postweaning growth, feed efficiency and chemical composition of sheep as affected by prenatal and postnatal testosterone. J. Anim. Sci. 66:1179-1185. 1988.

Klindt, J., Ford, J. J. Macdonald, G. J. Synergism of testosterone propionate with growth hormone in promoting growth of hypophysectomized rats: effect of sexual differentiation. J. Endocrinol. 127:249-256. 1990.

Ram Mating Behavior: How is it Affected by Sexual Experience and Season of the Year?

Kurt E. Borg, Donald D. Lunstra, and J. Joe Ford[1]

Introduction

The reproductive and hormone secretion system of the ram is inhibited by increasing daylength during the spring and summer, much as is seen during the anestrous period for the ewe. During this time of the year, the ram typically is not sterile, but exhibits lower levels of sexual aggressiveness, decreased testosterone secretion, decreased testis size, decreased sperm output, and consequently lower fertility. Generally, these factors improve in the fall and ram fertility returns to normal, but some rams still exhibit a lower mating activity.

The sheep industry as a whole is also aware of the prevalence of rams that will not mate in a given ewe flock. The causes of this phenomenon have not been adequately studied. Thus, an experiment was designed to determine the effects of season and previous mating experience on the behavioral and hormonal responses of rams to estrous ewes.

Procedure

Twenty-four mature (2 and 3 years of age) crossbred rams (½ Finnish Landrace, ¼ Suffolk, ¼ Targhee) were studied in June and October (12 each season). Six rams in each season were sexually experienced (having previously been used for flock mating). The other six rams in each season were sexually naive (no contact with ewes since weaning). Animals were acclimated to human contact and to the experimental protocol (testing area) for two weeks before each trial. To facilitate blood sampling without disrupting ram-ewe interactions, a jugular cannula was inserted the day before each trial. In each season, three 15-minute treatments were applied in sequence to each ram: 1) placed into an empty pen; 2) placed with two estrous-restrained ewes and contact limited to naso-genital only; and 3) placed with two restrained estrous ewes and complete ram-ewe contact allowed.

Blood samples for measurement of luteinizing hormone and testosterone were collected at 15-minute intervals during the

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2 hours before and after each treatment and at 5-minute intervals during each 15-minute treatment. In addition, sexual behavior (nudges, vocalizations, licks, sniffs, flehmens (lip curls), mounts, and ejaculations) were recorded during ewe exposure.

Results

During limited contact trials with estrous ewes, sexually experienced rams engaged in more vocalizing, licking, sniffing and nudging of the ewes than did sexually naive rams (Table 1). Activity of inexperienced rams only exceeded that of experienced rams for number of prolonged flehmen responses (lip curls). For all of these sexual behaviors (hereafter termed courtship behaviors), frequencies were consistently and significantly greater in all rams during the fall than in the summer, with the exception of brief flehmen responses.

During complete contact trials with estrous ewes, all sexually experienced rams successfully completed at least one intromission with ejaculation during the 15-minute exposure in both summer and fall (Table 2). The sexually inexperienced rams, however, were less able to mate an estrous ewe. During the summer, only 33% (two of six rams) completed a mating. In the fall, the number of sexually naive rams breeding a ewe increased to 66% (four of six rams). Rams that achieved at least one service engaged more frequently in courtship behaviors (vocalization, licking, sniffing, brief flehmen response of less than three seconds duration, and nudging of the ewe) than did non-mating rams (Table 2). Sexually experienced rams showed significantly more servicing, mounting, and licking behaviors as compared to inexperienced rams. However, the inexperienced rams engaged in more vocalization and sniffing of ewes and display of brief flehmens than did experienced rams. Overall, almost all behavioral activities were exhibited more frequently in the fall than in the summer.

Concentrations of luteinizing hormone and testosterone were greater in sexually experienced rams than in sexually inexperienced rams. Luteinizing hormone was greater in the summer than in the fall, but testosterone concentrations were

Table 1—Frequencies of behaviors exhibited by rams allowed limited contact (naso-genital) during a single 15-minute exposure to estrous females[a]

| No. Rams Behavior[d] | Experience[b] | | Season[c] | | |
	12 SE	12 SI	12 June	12 October	24 Overall
Vocal	5.4 ± 0.7*	1.3 ± .2	1.3 ± .2	5.5 ± .7*	3.4 ± .4
Lick	14.2 ± 1.4*	3.2 ± .5	3.2 ± .4	14.2 ± 1.5*	8.7 ± .8
Sniff	27.6 ± 1.3*	12.2 ± .7	15.1 ± .8	24.7 ± 1.5*	19.9 ± .9
Brflehm	0.4 ± 0.1	0.4 ± .1	0.4 ± .1	0.4 ± .1	0.4 ± .1
Prflehm	0.3 ± 0.1	0.9 ± .2*	0.3 ± .1	1.0 ± .2*	0.6 ± .1
Nudge	12.2 ± 1.1*	1.5 ± .3	4.2 ± .6	9.5 ± 1.1*	6.8 ± .7

[a]Expressed as a mean ± SE
[b]SE = sexually experienced: SI = sexually inexperienced, significant differences in frequencies of behavior by level of experience are noted (*P < .001).
[c]June = nonbreeding season; October = breeding season; significantly greater frequencies of behaviors between trials are noted (*P < .001).
[d]Vocal = low pitch vocalization directed at ewe; Lick = licking of the ewe; Sniff = olfactory investigation of the ewe; Brflehm = brief flehmen (< 3 seconds in duration); Prflehm = prolonged flehmen (> 3 seconds), Nudge = nudging with shoulder and head at hind quarters of ewe

Table 2—Frequencies of behaviors exhibited by rams given the opportunity to mate during a single 15-minutes exposure to estrous females[a]

No. Rams Behavior[e]	Copulatory Response[b]		Experience[c]		Season[d]		
	18 Mating	6 Non-mating	12 SE	12 SI	12 June	12 October	24 Overall
Service	2.4 ± .1**	0.0 ± .0	2.3 ± .1**	1.3 ± .1	1.8 ± .1	1.9 ± .1*	1.8 ± .1
Mounts	7.8 ± .3**	0.0 ± .0	8.2 ± .3**	3.6 ± .3	2.5 ± .1	9.3 ± .4**	5.9 ± .2
Vocal	19.3 ± .7**	1.7 ± .1	13.7 ± .7	15.9 ± .8*	5.0 ± .3	24.6 ± .9**	14.8 ± .6
Lick	13.4 ± .6**	1.3 ± .1	15.0 ± .9**	5.8 ± .3	3.6 ± .3	17.3 ± .9**	10.4 ± .5
Sniff	14.6 ± .2**	10.7 ± .2	13.3 ± .2	13.9 ± .2*	12.5 ± .2	14.7 ± .2**	13.6 ± .2
Brflehm	0.8 ± .1**	0.2 ± .1	0.3 ± .1	1.1 ± .1**	0.9 ± .1**	0.4 ± .1	0.7 ± .1
Prflehm	0.3 ± .1	0.3 ± .1	0.3 ± .1	0.3 ± .1	0.1 ± .1	0.6 ± .1**	0.3 ± .1
Nudge	18.0 ± .5**	3.3 ± .2	14.2 ± .6	14.5 ± .6	8.4 ± .4	20.3 ± .6**	14.3 ± .4

[a]Expressed as a mean ± SE.

[b]Mating rams exhibited significantly greater frequencies of behaviors than non-mating rams (**P < .001).

[c]SE = sexually experienced; SI = sexually inexperienced; significant differences in frequencies of behaviors by level of experience are noted (*P < .05; **P < .001).

[d]June = nonbreeding season; October = breeding season; significantly greater frequencies of behaviors between trials are noted (*P < .05; **P < .001).

[e]Service = intromission with ejaculation; Mounts = rear-oriented mount of ewe; Vocal = low pitch vocalization directed at ewe; Lick = licking of the ewe; Sniff = olfactory investigation of the ewe; Brflehm = brief flehmen (<3 seconds in duration); Prflehm = prolonged flehmen (>3 seconds); Nudge = nudging with shoulder and head at hind quarters of ewe.

higher in the fall than in the summer. Concentrations of luteinizing hormone were increased during the limited and complete female contact tests compared to the empty pen test.

Testosterone concentrations showed a similar trend. However, levels of testosterone were higher in the limited contact tests than in the complete contact tests. Correlations between courtship behaviors and hormone concentrations indicated that higher numbers of investigations of the estrous ewe (licking, sniffing, and nudging) were highly related to increases in hormone concentrations.

These experiments demonstrated that season and previous sexual experience influences the behavioral and hormonal responses of the ram to a brief 15-minute exposure to estrous ewes. Little information is available on the effects of sexual experience on luteinizing hormone and testosterone concentrations in rams. Data that are available suggest that rams that refuse to copulate with an estrous ewe exhibit fewer luteinizing hormone peaks than do rams that mate with estrous ewes. Mature rams with known previous breeding histories were utilized in the current study. Sexually inexperienced rams in our study had lower mating activity and lower hormone levels, and differences in sexual experience may explain the difference in hormone levels and

mating activity reported in other studies. The different sexual behavior of the sexually naive ram may stem from nervousness and confusion. Presence of new sexual odors (pheromones) probably caused the increased sniffing and flehmen activities exhibited by the sexually naive ram when allowed complete contact with ewes. Confusion and nervousness probably caused the increased vocalizing activities exhibited by sexually naive rams (Table 2). An increased level of nervousness has been associated with increased number of vocalizations in sheep when an animal becomes isolated from its flock.

In summary, mating, level of sexual experience, and season altered the hormone levels and behavioral activity of rams upon exposure to estrous ewes. Frequencies of reproductive behaviors displayed by rams were highest during the breeding season (fall). Changes in concentrations of luteinizing hormone and testosterone were more influenced by season and previous sexual experience than by mating activity. These results indicate that proper ram management should include periodic exposure to ewes prior to the breeding season to better prepare the ram for the time when he is to be utilized as a flock sire. More information is needed to obtain a better understanding of the behavioral processes of rams during contact with receptive females.

Nutritional and Body Condition Effects on Ovulation Rate and Hormone Profiles in Finnish Landrace Cross Ewes

Stewart M. Rhind and Bruce D. Schanbacher[1]

Introduction

In many sheep breeds, lambing rate is governed by the nutrition of the ewe before and during mating. Ewes which are in good body condition (fat) at mating generally have a higher lambing rate than ewes in low body condition (thin). Increasing feed intake (flushing) for many of these breeds during the days or weeks before mating usually enhances reproductive performance. These effects of nutrition on lambing rate are largely due to effects on the ewe's ovulation rate (number of eggs shed). The ovulation rate in turn is dependent on the number of developing follicles present on the ovaries; each follicle produces a single egg. Because not all of the follicles reach maturity, ovulation rates of ewes on different nutritional levels also depend on the relative numbers of the follicles which are induced to mature and shed an egg.

In Finnish Landrace ewes and their crosses, however, ovulation rate is largely independent of nutritional factors. The underlying functions of ovarian follicle development and the patterns of hormone secretion which control them are not known. This experiment was designed to investigate the effects of body condition and level of feed intake on the numbers, sizes and physiological state of ovarian follicles present in Finn cross ewes and how this reflects on their ovulation rate. A further objective of this project was to describe the hormone changes associated with different levels of nutrition in order to better understand follicle development and ovulation rate.

Procedure

Forty Finnish Landrace x (Dorset x Rambouillet) ewes with an initial liveweight of 150 lb and average body condition score of 2.45 (5-point scale: 1 = emaciated, 5 = obese) were assigned to treatment in November 1988. Group I ewes (LM, low body condition, maintenance diet) were initially fed a restricted ration of corn silage and complete pelleted ration to achieve a condition score of 2.0 by 3 weeks before the time of the study. The remaining 28 ewes (Group II) were fed to maintain liveweight and a condition score of 2.5 (MM, moderate body condition, maintenance diet; and MAL, moderate body condition, *ad libitum*—fed all they wished to eat). Beginning three weeks before the study, ewes were fed as follows:

Low Maintenance Group (LM) (12 ewes) — 1.8 lb/head/day, ewes received a complete pelleted ration; ration was designed to maintain ewes at same low condition score and liveweight.

Moderate Maintenance Group (MM) (15 ewes) — 2.2 lb/head/day, ewes received the same ration; designed to maintain ewes at a higher condition score and liveweight than that of the low maintenance ewes.

Full Fed Group (MAL) (13 ewes) — ewes were fed the same pelleted ration ad libitum (as much as they wanted); intake was increased over a 7-day period so that during the 2 weeks before the study the ewes had a much higher feed intake than the moderate maintenance ewes.

Estrous cycles were synchronized using intravaginal progestagen pessaries inserted for a 14-day period. On the 9th day after the pessaries were removed, blood samples were collected from all ewes by jugular catheter at 20-min intervals for 8 hours. On the 12th day after the pessaries were removed, all ewes were injected intramuscularly with prostaglandin $F_{2\alpha}$ (PG). After that, blood samples were collected at 4-hour intervals for 60 hours from the time of the prostaglandin injection and at 10-min intervals from 20 to 24 hours and 32 to 36 hours after the prostaglandin injection for determination of hormone profiles. All ewes were slaughtered 8 days after the prostaglandin injection and their ovaries were recovered and follicles counted, measured and their estrogen content determined. The numbers of eggs shed after the prostaglandin injection were determined from the numbers of corpora lutea present in the ovaries at slaughter.

Results

The treatment differences in body condition scores prescribed for the low maintenance ewes (LM) and the moderate maintenance (MM) ewes were largely achieved and maintained until samples were collected (Table 1). The average liveweight and condition score of the *ad libitum* fed ewes were slightly higher than those of the moderate maintenance ewes at the time of the study, but their daily intake of 4.3 lb/head was almost twice as high as that of moderate maintenance ewes.

Kidney fat depth measurements at slaughter were consistent with the condition score measurements.

Table 1—Average liveweights (lb) and condition scores 2 weeks before (wk -2) and at time of blood sample collection (wk 0) and mean kidney fat depths (inches) at slaughter

	MAL	MM	LM
Liveweights, lb			
week -2	148	150	134
week 0	151	145	131
Condition scores[a]			
week -2	2.46	2.52	2.19
week 0	2.65	2.53	2.15
Kidney fat depth at slaughter, inches	.16	.16	.09

[a]Condition score (5 point scale: 1 = emaciated, 5 = obese).

Similar numbers of large ($\geq$ .16 inches in diameter) follicles and number of corpora lutea were present in ewes of all treatment groups (Table 2). Because of this finding, the result of this study indicate that, unlike many other breeds of ewe, neither ewe body condition nor feed intake affects the numbers of large antral follicles available for ovulation in ewes of this breed.

Generally, only a proportion of large follicles have the capacity to mature and shed an egg. Because of this it is important to classify whether follicles are healthy or non-healthy (atretic). Large, healthy follicles contain follicular fluid with high concentrations of the hormone estradiol (a form of estrogen). The follicles were therefore classified on the basis of their estradiol content as non-estrogenic (< 10 picograms

Table 2—Numbers of large ovarian follicles (≥ .16 inches in diameter) and corpora luteal (CL) present at slaughter

	MAL	MM	LM
No. follicles (≥ .16 inches) per ewe	2.92	2.64	2.45
Range	2-5	2-4	2-3
No. of CL/ewe ovulating	2.77	2.47	2.27
Range	2-4	2-4	1-3
Ratio of CL and large follicles	0.95	0.94	0.93

per cc), estrogenic (10-50 picograms per cc) or highly estrogenic (> 50 picograms per cc). Those in the last two categories were considered to be healthy and to be potentially capable of maturation (estrogenic follicles) or were already mature and ready to ovulate (highly estrogenic follicles).

A high proportion (77-96%) of the large (≥ .16 inches in diameter) follicles were either estrogenic or highly estrogenic in all treatments (Table 3) and in 78% of the ewes all large follicles present at slaughter were in these classes. Levels of body condition and of feed intake had little or no effect on the proportion of large, non-estrogenic follicles (Table 3). This work indicates that most large follicles were potentially ovulatory in ewes of all treatments.

When the ewes were slaughtered, the populations of corpora lutea and of large follicles found were formed at different times and are not directly comparable. However, it is reasonable to assume that the corpora lutea found at slaughter came from a population of ovarian follicles similar to the follicles found at slaughter. Therefore, the follicle and corpora lutea numbers studied together indicate that over 90% of the large follicles that developed would have ovulated. It was also observed that the same proportion of these follicles were estrogenic and had the potential to ovulate.

Follicle fluid concentrations were analyzed for two addi-

tional reproductive hormones, inhibin and insulin-like growth factor-1 (IGF-1). Results summarized in Table 4. While insulin-like growth factors-1 in the follicle were not influenced by ewe body condition or feed intake, average inhibin concentrations were significantly higher ($P < 0.01$) in follicles of ewes in the low body condition.

Concentrations of inhibin in the blood stream before and for at least part of the time after the prostaglandin injections were closely related to the concentrations of inhibin in the follicles, (Figures 1 and 2) although fluid concentrations in the follicle were about 1000 times higher. Concentrations of insulin-like growth factors-1 in the blood stream did not show any relationship to (Figures 1 concentrations in the follicles. This difference may reflect the fact that inhibin is for the most part produced in the ovary while there are both intra- and extra-follicular sources of insulin-like growth factors-1 in the body.

Although follicle stimulating hormone (FSH) concentrations were not affected by the nutritional treatments, during the preovulation phase of the estrus cycle, luteinizing hormone (LH) concentrations, the rate of secretion releases per hour (pulse frequencies) were higher in ewes in average body condition than in ewes in low condition and were lower in ewes fed *ad libitum* (Table 5). This observation, never-the-less, did not affect the ovulation rate of these ewes, as might be suspected.

Because follicle populations and ovulation rates were similar and insulin-like growth factor-1, inhibin, and luteinizing hormone were different for the three nutritional treatments, we suggest ovulation rate is not under the control of these hormonal factors alone.

In conclusion, in Finn cross ewes a very high proportion of large ovarian follicles are estrogenic regardless of the ewe's body condition and most of these follicles apparently mature and ovulate regardless of the level of ewe feed intake. The hormonal mechanisms through which this pattern of follicle development is controlled is still not clear.

Table 3—Numbers and proportions of large follicles in each treatment classified as non-estrogenic, estrogenic, or highly estrongenic

	MAL		MM		LM	
	No.	Pro-portion	No.	Pro-portion	No.	Pro-portion
Non-estrogenic (< 10 ng/cc)	8	0.24	8	0.22	1	0.03
Estrogenic (10-50 ng/cc)	24	0.71	21	0.58	21	0.72
Highly estrogenic (> 50 ng/cc)	2	0.06	7	0.19	7	0.24

Table 4—Average concentrations of inhibin (picomole per cc) and insulin-like growth factor – 1 (IGF – 1, nanogram per cc) in large ovarian follicles (≥ .16 inches in diameter

	MAL	MM	LM	Effect of treatment		Effect of follicle class
				MM vs LM	MAL vs MM	
Inhibin						
Non-estrogenic	93.8	57.5	134.3	* *	*	
Estrogenic	101.2	101.2	136.4	* * *	NS	* *
Highly estrogenic	84.3	94.6	187.9	* * *	NS	
IGF – 1						
Non-estrogenic	48.0	40.4	– –	– –	NS	
Estrogenic	95.0	107.8	101.3	NS	NS	NS
Highly estrogenic	97.1	108.2	144.9	NS	NS	

*$P < 0.05$
**$P < 0.01$
***$P < 0.001$
NS Non significant

Table 5—Average concentrations of LH (nanogram per cc) and average LH pulse amplitudes (nanogram per cc) and pulse frequencies (pulses per hr) in ewes of each treatment group during the luteal and follicular phases of the cycle

	MAL	MM	LM	Effect of treatment MM vs LM	Effect of treatment MAL vs MM
Luteal					
number of ewes	13	15	12		
LH					
concentration	1.20	1.39	1.38	NS	* * *
pulse amplitude	2.23	2.71	2.80	NS	NS
pulse frequency	0.26	0.20	0.27	NS	NS
Early follicular					
number of ewes	11	14	12		
LH					
concentration	1.83	2.09	1.83	* * *	* * *
pulse amplitude	2.60	3.12	2.44	*	*
pulse frequency	0.68	0.75	0.67	NS	NS
Late follicular					
number of ewes	11	14	12		
LH					
concentration	2.06	2.85	2.50	* * *	* * *
pulse amplitude	3.04	4.39	3.58	* *	* * *
pulse frequency	0.73	0.88	0.65	* *	NS

*$P < 0.05$
**$P < 0.01$
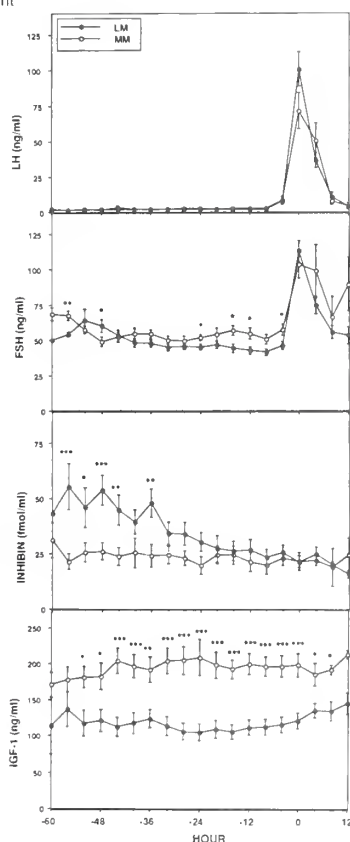***$P < 0.001$
NS Non significant

Figure 1 – Serum profiles of luteinizing hormone (LH), follicle stimulating hormone (FSH), inhibin and insulin-like growth factor-1 (IGF-1) for 60 hr before and 12 hr after onset of the preovulatory LH surge in ewes in moderate (MM) and low (LM) body condition and fed a liveweight maintenance ration. Significance of differences between treatments is indicated at each sampling time (* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$).
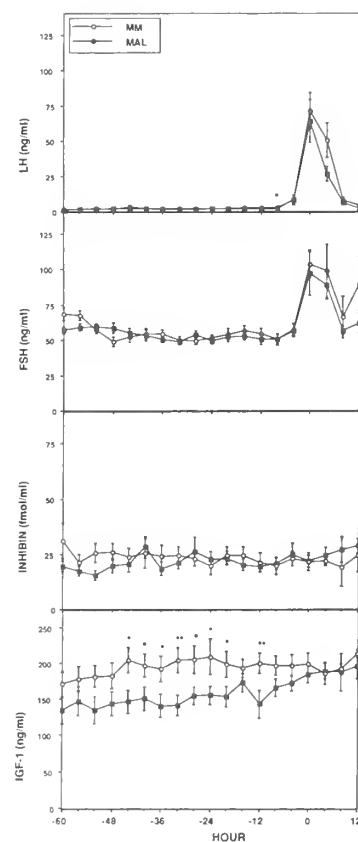

Figure 2 – Serum profiles of luteinizing hormone (LH), follicle stimulating hormone (FSH), inhibin and insulin-like growth factor 1 (IGF-1) for 60 hr before and 12 hr after onset of the preovulatory LH surge in ewes in moderate body condition and fed either ad libitum (MAL) or a liveweight maintenance ration (MM). Significance of differences between treatments is indicated at each sampling time (* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$).

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